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P R E F A C E.

IN drawing attention to the peculiar character of the present work, it is only necessary to quote the following sentences from the Directory of the Science and Art Department of the Committee of Council on Education issued in September 1876 :—

“The Lords of the Committee of Council on Education having considered the Science Directory in relation to the aid now given through the Code in England and Scotland, and by the Commissioners of National Education in Ireland, towards instruction in some branches of Science, and in Geography, are of opinion that the subject of Physical Geography, as now defined in the Science Directory, is not one towards instruction in which the special aid of the Science and Art Department should be continued.

“The outlines of the syllabus of a subject which will take the place of Physical Geography are now under consideration. Due notice will be given when they have been settled. The subject (Physiography) will embrace those external relations and conditions of the earth which form the common basis of the Sciences of Nautical Astronomy, Geology, and Biology, as treated in the Science Directory.”

The syllabus referred to was issued early in 1877, when it became apparent that a great variety of subjects had been introduced under “Physiography” that had no place in any existing school-book treating of Physical Geography.

By glancing at the Table of Contents, the student will at once perceive that the Author has discussed, with all the fulness his limited space would allow, all the subjects embraced in the new syllabus, and has given special prominence to every topic now appearing for the first time—such as Astronomy, Geology, Biology, Spectrum Analysis, Optical Instruments, Geodesy, and Map Projections.

HATTON PLACE, EDINBURGH,
August 1877.

* * Since the first impression of this little work was thrown off—now nearly two months ago—various important discoveries in physical science have been announced. Of these the following are, perhaps, the most interesting to the students of physiography: (1) Professor Hall of Washington has discovered that the planet Mars is attended by two small satellites. Probably, therefore, the satellites belonging to the solar system form a regular series, of which the four first terms are complete—thus, the Earth has 1 satellite, Mars 2, Jupiter 4, Saturn 8. According to this, Uranus should have 16, and Neptune 32, though, as yet, only a few of them have been seen. (2) In the region of the Asteroids 5 minor planets have been detected, thus raising the entire number to 174. (3) The Washington astronomers have assigned a new rotation period to Saturn—viz., 10 h. 14 m. 24 s.—instead of the time indicated at page 9. (4) A new metal has been discovered by a Swedish naturalist, and named Davium, in honour of the great English chemist, Sir H. Davy. (5) By aid of the spectroscope, an additional element—oxygen—has been detected in the sun. (6) But by far the most important announcement is the new distance assigned to the sun by the British astronomers who observed the last transit of Venus. They give the sun's parallax at 8.760", and his mean distance from the earth as 93,300,000 miles (see p. 9). This astounding result cannot possibly be accepted as the final verdict of science, seeing that it greatly differs from all former estimates, including that derived from Mars when last in opposition, and more especially from the distance assigned by the French observers of the very same transit (see p. 140). Meanwhile, every lover of truth must suspend his judgment till the other Governments that sent expeditions to observe the transit of Venus give their respective estimates, and probably till the more favourable transit of 1882 puts the matter beyond all dispute.

EDINBURGH, *15th October 1877.*

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PHYSIOGRAPHY

AND PHYSICAL GEOGRAPHY.

GEOGRAPHY, as the name implies, is the science which treats of the Earth, or temporal abode of Man. The Germans call it *Erdkunde*—that is, *Knowledge of the Earth*, certainly one of the most important branches of all human knowledge.

But the Earth may be regarded from many different points of view, each of which affords material for a new and different science. Thus, if we regard the Earth as a member of the Solar System, it supplies ASTRONOMY with its most interesting and valuable chapter. If we inquire into its origin, age, materials, and history through the lengthened ages of the past, we find ourselves, at once, in the very heart of GEOLOGY. If we confine our view to its present surface and physical state, thus commencing our inquiries where Geology terminates, we have PHYSICAL GEOGRAPHY. If we investigate the true causes of the phenomena brought under our notice by Physical Geography—if we regard the Earth as the theatre where all the forces and laws of Nature are displayed in their infinite variety and interdependence—and if we explain the methods and instruments by which our knowledge of Nature has been arrived at, we find ourselves studying PHYSIOGRAPHY (*physis*, nature, *graphie*, a description), *i.e.*, the science of Nature,—a science which is intimately connected with Chemistry, Meteorology, Electricity, Magnetism, and Ethnography; while it especially treats of “those external relations and conditions of the Earth which form the common basis of Nautical Astronomy, Geology, and Biology.”* Thus Physiography cannot be separated from Physical Geography, which in truth is its foundation; nor can any clear line of distinction be drawn between it and the various natural sciences above enumerated, each of which yields to it its own contribution.

* See ‘Directory of Science and Art Department,’ September 1876, p. 4.

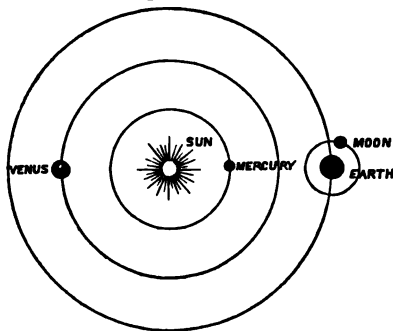
I.—MATHEMATICAL GEOGRAPHY;

OR, THE EARTH AS A MEMBER OF THE SOLAR SYSTEM.

Mathematical Geography is that part of Astronomy which treats of the Earth as a member of the Solar System, or of that great family of planets, satellites, comets, and meteorites which circulate round the central luminary, deriving from him their light, heat, and other influences.

The Solar System.—In order to form a correct idea of the earth, we must not regard it as an isolated independent body, having no relation to other worlds, but as a member of a large family or system of similar bodies, all of which revolve round the sun, at different distances, and with different degrees of velocity. These bodies are collectively known as the SOLAR SYSTEM, from the fact that the sun (Lat. *sol*) is by far the largest body belonging to it; that he is placed in the centre, all the other members revolving around him, either directly or indirectly; and especially to distinguish it from the numberless other systems that are located around it in universal space, each of which has probably its own sun or star as the immediate

centre of its light, heat, and gravitating power.



The accompanying diagram represents only the Sun and the three interior planets nearest him, including the Earth with her satellite. Beyond the orbit of the Earth is Mars, after which comes the group of small planets, then Jupiter, Saturn, Uranus, and Neptune, whose distances from the Sun, with many other particulars, will be found in the tables of the Solar System, p. 9.

Besides the great central luminary, this system consists of 178 distinct bodies called planets, more or less like our earth; of 18 moons or satellites revolving around the 5 largest planets; of a vast number of luminous bodies named comets, all of which move around the sun in very elliptical orbits and with inconceivable velocity; and of a countless number of very small opaque bodies termed meteorites. All these are united together in one beautiful and harmonious whole by the mysterious power of gravitation—a power communicated to every particle

of matter in the universe by the All-wise and Omnipotent Creator.

The Sun.—The grand central orb of this stupendous piece of mechanism is the Sun, the most glorious and magnificent object in nature. In size or **volume** he is 1,245,000 times that of the Earth, his diameter being 852,380 miles; but his **mass** or weight is only 314,000 times the weight of the earth, or 742 times that of all the planets and satellites combined. The materials, therefore, of which the sun is composed, are much less densely packed together than in our planet. In other words, his **specific gravity** is greatly less, being only one-fourth that of the earth. Contrary to former notions, it is now established that the sun is not stationary, but **moves through space** at the rate of 5 miles per second, or 150,000,000 miles per year; that he rotates around his axis in 25 days, 7 hours, 48 minutes; and that his distance from the earth is about 92,093,000 miles. Owing to his low specific gravity, and the vast distance between his centre and circumference, the force of gravity at the sun's surface is only 27.2 times its force at the surface of the earth. Now it is well known that heat expands bodies, and so diminishes their specific gravity; and as the heat of the sun must be inconceivably intense, it follows that, in all probability, the materials of which he is composed are in a gaseous state, for we cannot imagine it possible that material substances can subsist in the solid form at such a high temperature. The specific gravity of the sun, though four times less than that of the earth, may appear to be greatly too high on the supposition that he is a gaseous body; but we must remember that, owing to the vastness of his mass, the force of gravity exercises an enormous pressure, thus compressing the gaseous materials to an extreme degree. The heat of the sun is so great that, in common with the fixed stars, he is self-luminous. Not only does he shine with unborrowed light, but that light is so intense that it powerfully illuminates all the planets and satellites which, at such vast distances, revolve around him. Indeed it has been calculated that the heat thrown out by every square yard of the sun's surface is as great as would be produced by burning 6 tons of coals on it every hour. Then in regard to his **brightness**, Sir John Herschel found that it exceeds in brilliancy the brightest artificial light we can produce—viz., the lime-light (formed by a flame of oxygen and hydrogen playing on a ball of lime made intensely hot)—at least 146 times.

In regard to the **transmission of light and heat** from the sun to the earth and other planets, two leading theories have prevailed. Sir Isaac Newton held that the sun is constantly discharging from his surface inconceivable multitudes of extremely minute luminiferous particles of matter, capable of producing, when they strike against bodies, the phenomena of light and heat; but this theory, besides the improbability of a continual loss of substance without any diminution of brilliancy, cannot satisfactorily explain many of the phenomena in Optics that have been observed since Newton's day. The theory now most generally accepted is, that light and heat are

produced by *vibrations* or *undulations* in a thin, highly elastic fluid called *Ether* diffused throughout space. This fluid is supposed to be excited by the presence of hot and luminous bodies into undulations, which are capable of producing impressions of light and heat on bodies encountering them.

Viewed by the naked eye, or through a piece of stained glass, the sun presents a round, highly luminous disc, of uniform brightness, called the **Photosphere**; but seen through a telescope, large dark **spots** appear on his surface, principally near his equator. They move across the sun's disc in a westerly direction, and in an average period of 25 days, 7 hours, 48 minutes; this, therefore, is regarded as the time the sun takes to rotate on his axis. The spots are constantly varying in number, size, shape, and appearance; yet patient research into their appearance and disappearance has resulted in a series of interesting and important discoveries,—1. *The changes occur periodically in cycles of about 11 years*; 2. These periodic changes exactly correspond to the periodic changes of the earth's heat, rainfall, and magnetism. Professor C. P. Smyth has shown that a great wave of heat passes over the earth every 11 years, the wave commencing with the commencement of the sun-spots, while Meldrum, of the Mauritius Observatory, states that the *cyclones* of the Indian Ocean are most frequent in years of maximum sun-spots, and that the *rain-fall*, at least in tropical countries, is greatest in years of greatest solar disturbance. The spots are mainly confined to two narrow zones, one on either side of the equator, and extending from the 8th to the 35th degree. In the neighbourhood of the spots are what are termed **Faculae**, or bright patches, which are believed to be immense banks or ridges of vapour, of several thousands of miles in extent. Allied to these, though perhaps not identical, are the **Prominences** which are seen on the margin of the sun's disc during a total eclipse, and which consist of red masses of glowing vapour. These occur chiefly in the spot zone. Some appear for a few minutes only, while others are visible for several days. These Prominences, however, are but prolongations of the **Chromosphere**, which is a rim of red luminous matter surrounding the margin of the solar disc to a depth of some 3000 or 4000 miles. During total eclipses of the sun a still more extraordinary phenomenon, and one which has until recently baffled all attempts at explanation, is what is known as the **Corona**, which presents the appearance of a "glory" encircling the head of a saint in some Italian pictures. In the region immediately beyond the Prominences streaks of light shoot far up into the heavens, sometimes to a distance far exceeding the sun's diameter. This remarkable appearance was at different times attributed to a lunar or solar atmosphere. But the moon seems to have no atmosphere, and any atmosphere the sun may be possessed of cannot account in any satisfactory way for many of the phenomena. According to Proctor, the only satisfactory explanation is to regard the Corona as produced by the action of the solar heat on millions of *meteorites*, or small opaque bodies rapidly revolving around the sun in independent orbits, and rendered self-luminous by their proximity to the intensely heated

central luminary. This theory will account for all, or at least nearly all, the observed phenomena, and it wholly harmonises with what was already known regarding meteorites—as, for example, the myriads of meteoric stones which the earth encounters every year in her revolution round the sun, and which, coming within the sphere of her attraction, fall upon her surface; and the so-called **rings of Saturn**, which are now known to consist of an infinite number of very small satellites, chasing each other, in closely proximate orbits, around the planet. The 169 **small planets**, revolving round the sun between the orbits of Mars and Jupiter, probably afford another still more striking example; while the so-called **Zodiacal Light**, which has the appearance of a faint nebulous aurora surrounding the sun, and beyond the area of the Corona, must now be regarded as a mere continuation of the latter. Finally, as regards the **Physical Constitution** of the sun, modern science, aided by the **Spectroscope** (see below), has shown that the materials of which the sun is composed are not different from those of which the earth and planets are formed. Sodium was first discovered, and afterwards iron, magnesium, barium, copper, zinc, calcium, chromium, nickel, titanium, together with hydrogen, which is largely present, besides two other gases not yet identified.

The Planets.—The sun, in his journey through space, is accompanied by a number of dark bodies called planets (*wandering stars*), which revolve around him in nearly circular orbits, at different distances, and with widely different velocities. There are at present known to science 178 of these bodies, but every year is adding to the number. Nine of these (Vulcan, Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune) are bodies of vast size, some of them, indeed, greatly exceeding our earth in dimensions. The remaining 169 (known as **asteroids**, planetoids, or minor planets) are so small that until the present century they had eluded human observation. They are all situated between the orbits of Mars and Jupiter, where they fill a mighty gap in the system, and are possibly the fragments of an ordinary-sized disrupted planet. All the planets between the sun and this gap are named *interior* or *inferior** planets, while those more remote are known as *exterior* or *superior*. Besides being dark, opaque bodies, shining by reflected light derived from the central luminary, all the planets, large and small, possess the following common characteristics:—

1. They revolve round the sun in the same invariable direction, that direction being from west to east, or contrary to the motion of the hands of a watch—each revolution constituting the planet's *year*.
2. They revolve in elliptical, though nearly circular orbits, the sun being situated not in the centre but in one of the *foci* of the ellipse. The distance between the focus and centre of the ellipse is called the planet's *eccentricity*.
3. The planes of their orbits are more or less inclined to the ecliptic (or plane of the earth's orbit)—that is, to the plane of the sun's equator produced as far as Neptune.

* Some astronomers limit the word “interior” to those between the sun and earth, and “exterior” to all the rest.

4. They rotate on their axis like a spinning-top, and always in the same direction of west to east. Thus any spot on the surface of a planet is constantly moving eastward: such rotation constitutes the planet's *day*.

5. In all of them the axis of the planet is *inclined* to its own orbit, and not at right angles to it. Hence its days vary in length at different seasons of the year.

6. The axis of a planet constantly points to the same star, and is therefore parallel to itself throughout the year. On this great fact depends the planet's various *seasons*; the greater the inclination of the axis, the greater the contrast between the planet's summer and winter.

7. Their orbital velocity is greatest when nearest the sun (*perihelion*), and least when most remote (*aphelion*).

8. The greater the mean distance of a planet from the sun, the longer is its year.

9. The *radius-vector* (or line connecting the planet's centre with that of the sun) describes equal areas in equal times.

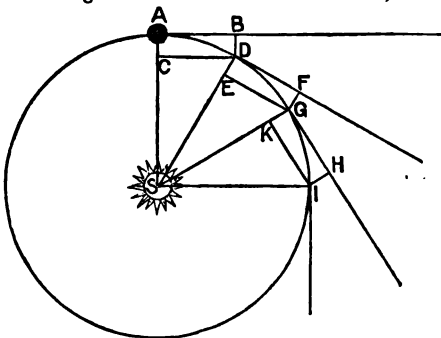
10. The squares of the periodic times of any two planets have the same ratio as the cubes of their mean distances.

Why the Planets move in Elliptical Orbits.—Elliptical motion is the result of the composition of two forces acting on the planet simultaneously, but in different directions. The first of these is called the *centrifugal* or *tangential force*, and is that which the planet received from the hand of the Creator when originally launched into space. This force, if unrestrained by any opposing one, would carry the planet wholly away from the sun, and project it into the depths of infinite space. But it is opposed or counteracted by the *centripetal force*, a force always acting at right angles to it, and directed towards the sun, or rather towards the centre of gravity of the entire system—a point situated within that body, though at a great distance from its centre. The latter force, again, if acting alone, would cause the planet to move towards the sun in a straight line, and with continually accelerated speed. But as both forces are incessantly operating, the planet must, in giving obedience to each of them, describe a curvilinear path.

The curve so described will, in every case, be one of the *conic sections*—that is to say, it will be one or other of the various curves obtained by cutting a cone in all the possible directions. It will depend, however, on the particular circumstances of the case—viz., direction, distance, and velocity—which of the curves shall be described—i.e., whether a circle, an ellipse, a parabola, or an hyperbola. Thus, the orbit will be a *circle*, when the square of the tangential velocity is equal to the diameter of the circle multiplied by the centripetal velocity; it will be an *ellipse*, when the former product is greater than the latter; a *parabola*, when the former product is exactly twice as great as the latter; an *hyperbola*, when more than twice as great; and, in every case, the angular velocity of the *radius-vector* must be inversely proportional to the square of the mutual distance of the two bodies.

In the accompanying diagram let A represent the earth and S the sun, and let us suppose that the earth, having been projected forward, is moving in a straight line with a velocity that would carry it on to B in

the space of a month, while the attraction of the sun, under whose influence it is moving, would bring it to C in the same time. Now, as the earth is impelled by two forces acting perpendicularly to each other, it is obvious that it will obey neither the one nor the other, but, like a ball struck at the same instant by opposite forces, it will move in a direction between them. It will not, however, like the ball, move in a straight line, or, as it is said, describe the diagonal of a parallelogram, because, as the



Orbital motion of a Planet.

power of attraction continues to act upon the earth without ceasing, it continually draws it out of the straight line, and thus converts its course into a *curve*. This is exemplified in the parallelogram A B D C, in the foregoing diagram. A D is the line described by the earth in the same time in which it would have described either the line A B or A C—that is, according to our supposition, in the space of a month. A D is of course a curved line, but as every point of it may be considered as constituting the diagonal of an infinitely small parallelogram, the earth may be said to move as a ball would under similar circumstances. The earth is now at D, and its tendency is to move in a straight line to F in the space of a month, while the attraction of the sun would bring it to E in the same period of time. But, as before, the earth will follow neither the one impulse nor the other, but will move between them in the line D G, which it will describe in the same time in which it would have described either the line D F or D E—that is, in the space of a month. We have now the earth at the point G, and its tendency is to move in a straight line to H in the space of a month, while the sun's attraction would carry it to K in the same time. But the combined action of these two forces will, as in the foregoing cases, cause the earth to move between them in a curved line—that is, it will describe the line G I in the same time in which it would have described either G H or G K.

The Interior and Exterior Planets compared.—The interior planets differ from the exterior in the following particulars: 1. The interior planets are all much smaller than the exterior. Thus the Earth, which is the largest of the former group, is only $\frac{1}{1000}$ part of the size of Jupiter, the largest of the latter. 2. All the interior planets are very near the sun as compared with the exterior, which are placed at vast distances. Thus the distance of Jupiter is five times that of the Earth, while Neptune, the most remote planet, is no less than thirty times further off. 3. The density of the interior planets is, on an average, six times greater than that of the exterior.

The specific gravity of Mercury, the nearest to the sun, is 1.24 times the density of the Earth, while that of Neptune, the most remote, is only .17, or $\frac{1}{6}$ of the former. 4. With the exception of the Earth, none of the interior planets possesses a satellite, while each of the exterior is attended by several. 5. The exterior planets, though very large, rotate on their axes much more rapidly than the interior—the average time of the former being 9h. 58m., and of the latter 24h. 6. The planes of the orbits of the interior planets are less inclined to the ecliptic than those of the exterior. Thus the orbit of Mercury makes an angle of 7° with the ecliptic, that of Venus $3\frac{1}{2}^\circ$, and that of Mars nearly 2° , while that of Jupiter is only $1^\circ 19'$ that of Saturn $2\frac{1}{2}^\circ$, that of Uranus $46'$, and that of Neptune $1^\circ 47'$.

The Earth as compared with the other Planets.—The more closely we compare our own globe with the other worlds in the solar system, the more we shall be satisfied that we are specially favoured, being exempted from all injurious extremes. 1. Its orbit lies in the plane of the sun's equator, all the others being more or less inclined to it. 2. Its orbit is but slightly eccentric, while its nearest approach to the sun occurs during the winter of the northern hemisphere, where the great bulk of the land is situated. 3. Its distance from the sun exempts it from burning heat and extreme cold. In a word, so far as we know, there is no *other planet* that presents conditions so favourable to animal life and enjoyment. Indeed it does not appear that any one of these bodies (unless Mars be an exception) is fitted to be the abode of any animal or plant with which we are acquainted.

Astronomical Tables.—The following tables—originally constructed by Professor C. Piazzi Smyth for 'Pillans' Physical and Classical Geography' (Edinburgh, 1854), and subsequently revised by him and brought down to the present state of astronomical science—give in detail all the most important of the numerous interesting facts hitherto ascertained regarding the different members of the solar system. On comparing these tables with those contained in the work referred to, it will be seen that astronomers have not been idle during the last quarter of a century; that numerous corrections and rectifications have been made in almost every column; and that, in particular, the great physical problem of the age—the true mean distance of the sun from the earth—has made rapid progress towards a satisfactory solution. That distance, it may now be confidently assumed, is 92,093,000 miles, for that is at once the grand mean of all recent researches, as also the number clearly indicated by that marvel of architecture, the Great Pyramid, now shown to have been erected B.C. 2170.

In accordance with the third law of Kepler, the Earth's distance from the sun determines the distances of all the other planets, the proper numbers for which have been drawn up by the indefatigable W. Petrie, civil engineer, whose labours have had no small share in solving the great problem referred to:—

THE SOLAR SYSTEM.

Names and order of the planets.	Mean distance from the sun in miles.	Periodic time of revolution in mean solar days.	Velocity in orbit per hour in miles.	Time of rotation on axis in solar days.	Amount of light—Earth = 1.	Number of moons.
SUN			17,583	days, ho. m. 25 7 48		
Vulcan	13,082,000	19.81	174,000			
Mercury	35,649,000	87.97	105,330	1 0 5	6.656	0
Venus	66,614,000	224.70	77,050	23 21	1.932	0
Earth	92,093,000	365.25	65,533	1 0 0	1.000	1
Mars	140,322,000	686.98	53,090	1 0 37	.436	0
Minor planets }	259,000,000	1,684.74	39,882	...	.130	0
Jupiter	479,141,098	4,332.62	28,744	9 55	.036	4
Saturn	878,461,000	10,759.30	21,221	10 29	.011	8
Uranus	1,766,565,000	30,686.82	14,963	9 30	.003	4
Neptune	2,766,133,000	60,126.71	11,958	...	.001	1

	Polar diameter in miles.	Equatorial diameter in miles.	Volume or size—Earth = 1.	Mass or weight—Earth = 1.	Density or specific gravity—Earth = 1.	Force of gravity at surface—Earth = 1.	Inclination of planet's equator to plane of orbit.
Sun	852,330	852,584	1,245,130.000	314,760.00	.25	27.20	" " "
Vulcan	785 ?	785 ?					
Mercury	2,062	3,050	.052	.07	1.24	1.15	
Venus	7,510	7,510	.851	.79	.92	.91	49 58 0
Earth	7,899	7,925	1.000	.00	1.00	1.00	23 27 24
Mars	4,086	4,920	.189	.12	.96	.50	28 51 0
Minor planets }	670	670					
Jupiter	83,151	88,400	1,367.481	300.86	.22	2.45	3 4 0
Saturn	64,714	71,904	746.898	90.03	.12	1.09	26 49 0
Uranus	29,722	33,024	72.359	12.64	.18	1.05	76 0 0
Neptune	36,620	36,620 ?	98.664	16.76	.17	1.20	26 0 0
Moon	2,159	2,159	.024	.018	.61	.17	1 32 0

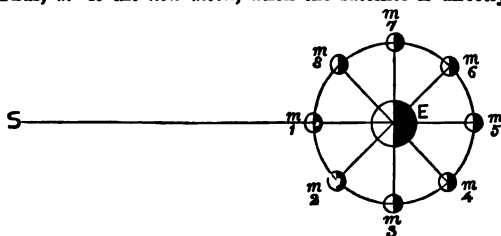
The Satellites.—As will be seen by the foregoing tables of the solar system, most of the planets are accompanied by one or more satellites or moons. These revolve around their primaries in the same way and in the same direction as the latter do around the sun, with the exception of the satellites of Uranus, which, strange to say, move from east to west. Moreover, all the satellites, like the planets, rotate on their axes in the same direction as their primaries (west to east). But it is a curious fact that any satellite's time of *rotation* is *precisely the same as its time of revolution* round its primary, thus

presenting to the planet the same invariable side. To this rule our own moon forms no exception. Of the eighteen moons known to belong to the solar system, no fewer than seventeen pertain to the four exterior planets, the earth being the only interior one that possesses such a companion.

In regard to the **Density** of the satellites, while the density of the moon is $\frac{3}{8}$ that of the earth, the satellites of Jupiter slightly exceed, on an average, that of the primary, being .288. Hitherto the densities of the other satellites have not been ascertained. In addition to his eight satellites, Saturn is accompanied by several colossal rings, which are now believed to consist of myriads of small opaque bodies, each moving independently and in its own orbit around the planet, but forming collectively a series of luminous streams, which in their nature resemble the meteorites through which our planet annually passes, and which circulate round the sun.

The Moon, or Earth's Satellite.—The Earth is more favoured than any other interior planet, by having an attendant satellite, the influence of which on our globe is fraught with numerous beneficial results. Among the most obvious of these we need only mention,—1. that being suspended aloft in the heavens she intercepts the sun's rays, and reflects them like a mirror on the side of the earth nearest her, thus giving us a beautiful though feeble and variable light during the sun's absence. A lunar day consists of 24 h. 50 m.

In the annexed diagram S represents the sun, E the earth, and *m* the moon, in eight different positions, and exhibiting eight different phases. Thus, *m*¹ is the *new moon*, when the satellite is directly between the

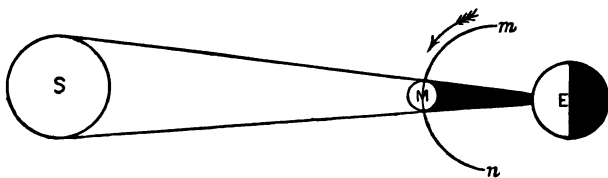


Phases of the Moon.

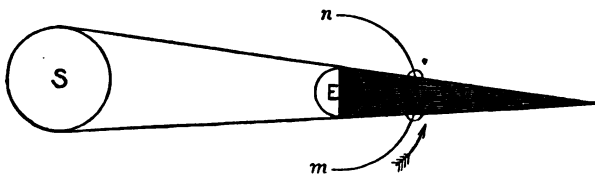
can see the whole of her enlightened surface; *m*⁷ the third quarter, when again we see half of her bright side, &c.

2. That, by powerfully attracting the earth's waters, she mainly causes and regulates the tides of our planet. 3. The moon has a great influence on our weather, as also on vegetation, especially in ripening the cereals. 4. Braun has recently shown that she also affects the earth's magnetism. The moon's polar diameter is 2158 miles, her volume $\frac{1}{49}$ that of the earth, but owing to her small specific gravity (0.61) her mass is only $\frac{1}{81}$ that of the latter. At the moon's surface a body would fall only $2\frac{1}{2}$ ft., instead of $16\frac{1}{2}$ ft. as with us. Her mean distance from the earth is 238,818 miles, or

part of our distance from the sun. Hence her attractive energy is greatly more powerful on our planet than that of the sun, the former being to the latter as 5 is to 2. Her time of revolution round the earth, as also her time of rotation on her axis, is 29d. 12h. 44m. Her orbit is inclined to that of the earth at an angle of $5^{\circ} 8'$, but for which we should have an eclipse of the sun and moon alternately every fortnight. There is a *total eclipse* of the sun when the moon is near the earth, and the sun, moon, and earth are in the same straight line; and an *annular eclipse* when, being more remote from the earth, her apparent diameter is less than that of the sun; and there is an eclipse of the moon when the earth comes between her and the sun, as the moon is then obscured by passing through the earth's



Total Eclipse of the Sun.

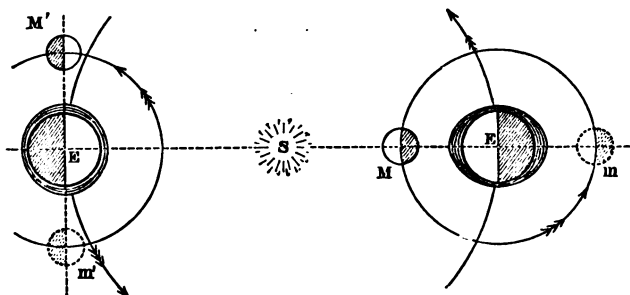


Eclipse of the Moon.

shadow. From the accompanying diagrams (in which *m*, *n*, represent the direction of the moon in her orbit), it will be seen that an eclipse of the sun can only take place at new moon, or when her dark side is towards the earth; while the moon can only be eclipsed when she is full, or has her bright side turned to us. The surface of the moon presents the aspect of a volcanic wilderness, being interspersed with enormous crateriform mountains, dykes, and lava streams, while no diversities of sea and land are discernible, and no atmosphere.

Tides.—The moon's attractive energy (aided by that of the sun at new and full moon) raises the waters of the ocean into a great tidal wave, which seems to follow the satellite in her path through the heavens. This attraction, however, directly accounts for only one high tide at any place every lunar day of 24 hours, 50 minutes; whereas, in reality, there are two high tides, occurring at intervals of 12 hours, 25 minutes. The other takes place at the same instant, but on the opposite side of the earth's surface, and is caused by the

moon drawing towards her the *nearer* or solid part of the planet (that is, its centre), with greater force than the *more distant* waters, which



thus remain in arrear, and apparently recede. When the moon is in the position M (*new moon*), or at m (*full moon*), it acts in *conjunction* with the sun. The tides on both sides of the earth are then at the highest, and are called *Spring* or *high tides*. But when the moon is at M' (*first quarter*), or at m' (*last quarter*), the waters rise the least, as the attraction of the sun, acting at right angles to that of the moon, considerably neutralises the effect of the latter, and produces what are known as *Neap* or *low tides*.

Other Members of the Solar System.—Besides the sun, planets, and satellites, there are vast numbers of other bodies belonging to the solar system, whose nature is less understood, but which doubtless perform very important functions in nature.

Comets.—The most notable of these are known by the name of comets (Gr. *comè*, hair), owing to their bearded or hairy appearance.



Comet of 1819.

They resemble rockets with sweeping tails of burning vapour, and consist of three parts:

1. The nucleus, or brightest and densest portion;
2. The coma, or cloud-like mass surrounding the nucleus;
- and 3. The tail (which becomes fainter the further it recedes from the nucleus), though many are destitute of that appendage. Like the planets, comets revolve round the sun, though

in very elliptical orbits, many of them, no doubt, forming parabolic curves, and never returning to visit our system. While the orbits

of the planets are nearly in the same plane as the ecliptic, those of the comets are highly inclined to it; and in regard to the majority of them (as Halley's), their orbital motion is in a direction contrary to that of the planets. The **distance** to which they recede from the sun varies greatly; for while the orbit of Encke's comet is within that of Jupiter, that of Halley's extends far beyond the orbit of Neptune. In like manner, their **periods of revolution** vary greatly, Encke's requiring $3\frac{1}{2}$ years, Biela's $6\frac{1}{2}$, Halley's $76\frac{1}{2}$ years; while the great comet of 1680 is supposed to have a period of 575 years, and that of 1811, 3065 years. At its *perihelion* (least distance from the sun), Newton believed this comet came within 150,000 miles of the sun, or $\frac{1}{4}$ of his diameter, and to have had a heat exceeding 2000 times that of red-hot iron! Comets are only visible when at or near their perihelion; and while some are so bright as to be seen in daylight by the naked eye, others can only be distinguished through the telescope. They are known to possess very small **density**, as the stars can sometimes be seen through their nucleus, or densest part. Though their apparent size is immense, their mass is so insignificant that when approaching the planets they produce no appreciable effect on them; while, on the other hand, the attraction of a planet frequently compels the comet to move in a totally different ellipse.

Meteors and Meteorites. — One of the greatest discoveries of modern astronomy is the very close connection subsisting between meteorites and comets. It has been found, for example, that the orbits of two well-known comets accord with those of the two best-known meteoric systems; while the spectroscope shows a similar identity of materials, which do not differ from those constituting the sun and planets. In fact, comets are now regarded as mere clouds of meteorites. Under the term meteors are included all those bodies which reach the earth's atmosphere from without. When they make their way unbroken through the atmosphere to the earth's surface they are known as **Meteorites**, or **Aerolites**, specimens of which may be seen in the British Museum; but when they explode during their passage through it, owing to the intense heat caused by their rapid motion through a resisting medium, they are termed **fire-balls**; and when the extreme heat has consumed them, leaving ashes and cinders only, they are called **shooting or falling stars**. It is now fully ascertained that all meteors, before approaching the earth, move round the sun in highly eccentric orbits, like the comets. In her annual journey round the sun, the earth encounters vast numbers of these bodies, especially between August and November; but as they are equally numerous within and without the earth's orbit, the number belonging to the solar system must be beyond all reckoning. It is now known that two well-marked meteoric systems travel in orbits of such enormous eccentricity as to be almost parabolic. One of these systems is what is known as the "August meteors," the orbit of which is identified with that of the comet III. of 1862. This comet is known to have a period of 145 years. The "November meteors," again, occupy a period of $33\frac{1}{2}$ years, and pursue the same track as Tempel's comet I., 1866. Astronomers believe that meteors in general follow

extremely elongated orbits, which are inclined to the ecliptic at all possible angles. The whole extent of the solar system is evidently strewn with meteoric systems, and it is calculated that one such system contains 100,000 millions of separate bodies. In general these bodies are very small, not exceeding a few ounces in weight, on an average, yet the aggregate weight of a system must amount to millions of tons. Now there must be myriads of such systems circling around the sun, some of whose members are incessantly falling on the earth and moon, and on every other planet and satellite belonging to our system. These are all, therefore, silently and slowly increasing in volume and mass. From his superior attraction the sun must draw towards him a vastly greater proportion of them than all the planets combined. They cannot avoid this fate, as they must often come into collision with each other, seeing they do not move in the same direction, nor with the same velocity. This collision must weaken or wholly destroy their velocity, and then they must infallibly be precipitated on the sun's surface. The nearer they approach the sun in their fall, the greater becomes their speed, so that when they come in contact with the solar mass the momentum must be tremendous, and the heat generated be intense beyond conception. Indeed it is here that we perceive the **great purpose and design** of these bodies. The light and heat proceeding from the sun is inconceivably intense, and without some supply from without, we cannot imagine it possible that in the course of ages they should not manifest some signs of abating. If these things be so, it is obvious that we have here the explanation of one of the greatest physical wonders in the universe.

II.—RELATION OF THE SOLAR SYSTEM TO THE UNIVERSE.

The Solar System forms but a very small part of the material universe. When we survey the heavens at night, we behold a multitude of luminous objects called *fixed stars*, which by their paler and more silvery light, and still more by their twinkling, are easily distinguished from such of the *planets* as can be seen by the naked eye, all of which shine with a yellowish, mellow, and steady ray.

Number of the Stars.—The fixed stars appear to the spectator to be of very different sizes, and this difference enables the astronomer to arrange them into classes, and thus to form some estimate of their number. Those visible to the naked eye are divided into six classes. The brightest are said to be of the first magnitude, and are about twenty in number, the seven brightest being Sirius, Canopus, Alpha Draconis, Arcturus, Riga, Capella, Vega; those of an inferior

degree of brightness, of the second magnitude; and so on, down to those of the sixth magnitude, or the smallest that can be seen without a telescope. The total number of stars visible to the naked eye, in a clear moonless night, is about 5000. It is only at the equator, however, that so large a number can be seen, for there only has the spectator the opportunity of seeing the whole heavens without altering his position. Should he take up his position at either of the poles, no more than half the starry firmament can ever pass in review before him; while at all intermediate positions, the number of stars visible in any one night will depend on the latitude of the place. Thus, the number visible to the naked eye at Berlin is about 3256. The telescope vastly extends our power of vision, and astronomers are familiar with stars of the *sixteenth* degree of magnitude. No fewer than 13,000 stars belong to the seventh magnitude alone; 20,000,000 belong to the first fourteen magnitudes; while the total number of stars visible by means of the best telescopes is estimated at 500,000,000,000, or half a million of millions!

Distance of the Stars.—The distance of the fixed stars from our sun is as inconceivable as their number, and till recently there were no reliable facts on which to build any probable calculation. In the year 1838, however, the parallax (or angle subtended by the diameter of the earth's orbit, as seen from a star) was measured in the case of three of them—viz., *Alpha Centauri*, 61 *Cygni*, and *Alpha Lyrae*, whose respective parallaxes were ascertained to be *one second*, *one-third of a second*, and a *quarter of a second*. The major diameter of the earth's orbit being about 184,186,000 miles, a parallax of one second will give a distance of twenty billions of miles, or 230,000 times the distance of the earth from the sun. This, then, is the probable distance of our sun from the nearest fixed star,—a distance so great, that light, which travels at the rate of 186,663 miles per second, would require $3\frac{1}{2}$ years to traverse it. The distance of the star 61 *Cygni*, its parallax being only one-third of a second, will be three times as great, and of *Alpha Lyrae* four times. The distance of 12 fixed stars is now approximately determined.

Magnitude of the Stars.—The actual magnitude of even the nearest of the fixed stars is still very uncertain; though it is the general belief of astronomers, founded on careful calculations, that many of them are greatly larger than our sun. Were our luminary and *Alpha Centauri*, for example, to exchange places, it is calculated that we should enjoy three times more light than we do at present, and hence, it is argued, that star is *five* times larger than our luminary. Sirius, dealt with in the same manner, would appear to have a volume exceeding that of the sun about 2700 times. But considerable uncertainty attaches to this method of determining the magnitude of the heavenly bodies; for the amount of light which reaches our world from a star does not depend on its magnitude alone, but also on its distance and intrinsic splendour.

Motion of the Stars.—The so-called “fixed stars” are, in reality, all in motion, and no fixed point—no object absolutely at rest—can be met with in the material universe. The power of gravitation,

which binds together the numerous members of the solar system, appears to be equally operative among the most distant objects in space. The *relative* distances of the fixed stars, and, consequently, the configuration of the constellations, are imperceptibly but daily altering. Of all the bright stars known to the ancients, not one has kept its place unchanged. While some vary only the twentieth part of a second annually, others vary from seven to eight seconds. Even our own sun, so long regarded as stationary, is now ascertained to be in rapid motion through space, carrying our earth and the other planets in his train, and traversing daily a distance of 432,000 miles,—a space exceeding his own radius. It will probably, however, be a long time yet before astronomers are in a position to determine whether this motion of our system through space is in a right line or curvilinear; and, if the latter, what that point is around which it is revolving. Dr Mädler of Dorpat has, indeed, hazarded the conjecture that our sun is only one of the millions of stars of the well-known Milky Way, which consists of a mighty ring, or wheel of stars, greatly crowded together at the circumference, but comparatively few towards the centre. The central group of this grand system which composes our firmament, is, he thinks, the Pleiades, which revolves round *Alcyone*, the brightest orb of that beautiful constellation. The distance of our sun from that centre of force he calculates at 81,500,000 times the distance of the earth from the sun,—a distance so great that light could not traverse it in less than 500 years, and requiring 18,200,000 years for our sun to complete one revolution! But however lofty such conceptions of genius may be, they are not, as yet, to be regarded as established scientific truths.*

Coloured Stars.—Besides differing in magnitude and brightness, stars display also the richest variety of colour. Viewed through the telescope, some are red or of a deep ruby, some orange or yellow, while others, generally the smaller companion stars, are blue, green, violet, indigo, &c. Thus, *Sirius*, *Capella*, &c., are white; *Procyon*, *Pollux*, and *Arcturus*, yellow; *Vega* and *Altair*, pale blue; *Antares* and *Aldebaran*, ruddy,—and so on. Among double stars, *complementary* colours are common,—the brighter star usually having a yellow, orange, or red colour, and the smaller, purple, blue, or green.

Variable Stars.—These present the singular phenomenon of a change in their brightness, undergoing a regular alternate increase and diminution of lustre, while several wholly disappear for a time. Some are remarkable for the shortness of their period of variation: thus *Algol* takes only 69 hours to complete its change; during 62 hours it shines as a star of the second magnitude, when it suddenly begins to wane to a star of the fourth magnitude, and returns to its former brilliancy in $3\frac{1}{2}$ hours more; while the star *Eta*, in *Argus*, takes 46 years to complete one such revolution. The cause of their variation of luminosity may be due either to their turning on their axes—one side of the star being, possibly, darker than the other; or to an opaque body, such as a planet, coming in periodically between

* On this subject see an important paper by Cockburn Muir, Esq., C.E., in 'Life from the Dead,' vol. iv. p. 166.

the star and the earth. From 200 to 300 stars are now recognised as variable.

Classification of Stars according to their Spectra.—The spectro-scope leaves no doubt that the stars more or less resemble our sun in their general constitution, their spectra being nearly identical with his. Minute differences, however, appear, which have enabled astronomers to divide them into four orders. The *first* includes those which shine with a white light. Their spectra show all the seven colours, crossed by multitudes of dark lines, and always by the four lines of hydrogen. The *second* includes most of the *yellow* stars. Their spectra exhibit the Fraunhofer lines, especially red and blue; and of all the four orders observed they appear most to resemble the sun in constitution. The *third* order embraces most of those shining with a red light, their spectra being somewhat like that of a sun-spot; and hence Secchi infers they are partly covered with spots like the sun. The *fourth* differs only from the last in the arrangement and appearance of the bands, and embraces only faint stars.

III.—THE EARTH VIEWED INDIVIDUALLY.

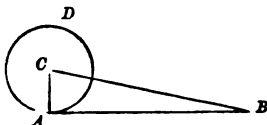
Having thus traced the relation of the Earth to surrounding worlds, we now return to examine that planet more minutely. Its *form* is that which a perfect sphere of semi-fluid consistency would assume, were it made to revolve around its axis with the same rapidity as the earth does. Such a form is called an *oblate spheroid*,*—that is, a sphere somewhat flattened or compressed at the poles, like an orange. The larger or equatorial diameter exceeds the polar diameter by 26 miles—the former being 7925, and the latter 7899 miles. In round numbers, the diameter may be stated at 8000 miles; the radius, or semi-diameter, at 4000; the circumference at 25,000; the area, or superficial content, at 197,000,000 sq. m.; the volume, or solid content, at 260,000,000,000 cubic miles; and the weight, or mass, at 6000 trillions of tons.†

* A *prolate* spheroid, on the contrary, is a sphere somewhat elongated in the direction of its poles, forming a body shaped like a lemon.

† Tyros in mathematics may be reminded of the following facts:—

1. The circumference of a circle, or sphere, whose diameter is 1, is = 3.1416, or $\frac{31}{8}$ nearly. Hence, to find the circumference of any other circle, or sphere, multiply its diameter by $\frac{31}{8}$.

2. The area of a circle is found by multiplying its radius by half its circumference. Thus the area of the circle $A D$ is equal to the area of the triangle $A B C$, the base of which, $A B$, is = the circumference of the circle. More briefly, area = $\frac{\text{rad.} \times \text{circ.}}{2}$.



Proofs of the Earth's Rotundity.—Among the numerous proofs of the spherical form of the earth, the following may be mentioned:—

1. A much greater extent of the earth's surface is visible from the top of a mountain than from a plain near the level of the sea.

2. As the mariner nears the land, he first sees the tops of the mountains; and, on approaching nearer, the lower grounds become visible.

3. In cutting for a canal, it is found that allowance must be made for a dip of about 8 inches per mile, in order to keep the water at a uniform level; while, approximately, the summit of a tower is visible at a distance of as many miles as the square root of its height in feet.

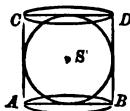
4. In travelling to any considerable distance, either north or south, new stars come to view in the direction in which the traveller is advancing, while others disappear in the direction from which he is receding.

5. Many navigators, who have sailed constantly in one direction, whether due east or due west, have returned to the port from which they set out.

6. The shadow which the earth casts on the moon, during an eclipse, is always circular.

7. All the other members of the solar system are spherical.

Standards of Metrology.—Very much depends on the exact determination of the size, shape, and mass of the planet which we inhabit, as on these depend, or at least *should* depend, all our standards of length, capacity, and weight. Almost every object in outward nature presents certain variations or fluctuations, in length and volume, according to temperature, pressure, and numerous other circumstances. Perhaps the sole really stable and unvarying line within the sphere of man's knowledge is the *polar diameter* of the earth. While all other measurable lines fluctuate in length, this has remained ever the same, at least since the earth became the abode of man. Modern science has approximately determined the length of this diameter to be 7899.17 English miles, and the polar radius (or man's distance from the centre of his earthly home) as 3949.585 miles. Reduced to *inches*, we have for the radius the number 250,250,000 inches. Now, let us divide this number by the length of the ancient sacred cubit (a cubit which, Sir Isaac Newton has shown, was 25.025 British inches), and we have the grand even number 10,000,000. The cubit, then, was the *ten-millionth part of the earth's polar radius*. That radius is all-important as a true standard of measure. If all civilised nations only agreed to employ this most ancient cubit as their standard of measure, all our present grievously conflicting measures (whether of length, capacity, or



3. The area of a sphere is equal to the *convex area* of the circumscribing cylinder, $A B C D$; and its solid content, S , is equal to $\frac{2}{3}$ of the solid content of the circumscribing cylinder.

Or, $\text{Area} = D^2 \times 3.1416$; $S = \frac{\text{rad.} \times \text{area}}{8}$; $\text{Weight} = 10^{15} \times$

$\text{weight of Great Pyramid} = 10^{15} \times 6,000,000 \text{ tons.}$

weight) would be infinitely simplified; and we should have one grand unvarying standard by which we could measure and weigh not only the material objects on the earth's surface, but also the earth itself and the other members of the solar system. We have seen that the sacred cubit is exactly $\frac{1}{10,000,000}$ th part of the earth's polar radius; whereas the much-vaunted French *mètre* (= 39.3708 British inches) is, or rather *was meant to be*, the 10,000,000th part of a *quadrant of the earth's meridian*. It is now ascertained, however, that no two meridians are of the same length, some of them being fully two miles longer than others; that no meridian is either a true circle, an ellipse, or any other mathematical curve; and that no man on earth knows, or ever did know, the length of that meridian which passes over Barcelona and Dunkirk. That short distance was the only portion measured by the French commissioners, in 1795, in their attempt to find an accurate basis for their new metrical system. The two places, however, are not on the same meridian; the Pyrenees formed a mighty obstacle in their way; and, at best, the difference of latitude between the two places was less than *ten degrees*! Therefore, however accurate the measurement might have been, they were not justified in regarding so small an arc as the *ninth part* of the distance from the equator to the pole. Assuredly, the more that exact science is cultivated, the more indefensible must become the French *mètre* as a true and accurate unit for the metrology of all nations.

MATERIALS, DENSITY, INTERNAL HEAT, AND ATTRACTIVE POWER OF THE EARTH.—Of the interior of the planet which we inhabit we know almost nothing, our observation being confined to a portion of its external crust, or rind, rarely exceeding 10 miles in depth, or $\frac{1}{400}$ of the distance from the surface to the centre. Even this insignificant distance is attained by adding the height of the loftiest known mountain to the depth below the sea-level of the deepest ocean-sounding. The geologist, however, without penetrating beneath the surface, but by carefully examining the order of superposition of the stratified rocks, has made us more or less acquainted with a depth of about 25 miles. Small as this portion is, when compared with the immense volume enclosed by it, it presents to our view a vast variety of substances, each of which has a character peculiar to itself. On examination, they are nearly all found to be *compound bodies*, which, on being analysed, are reducible to 65 *constituent elements*.

Constituents of the Earth's Crust.—These 65 elements the chemist divides into two groups,—the *Metallic* and the *Non-metallic* or *Metalloid*. The metals are 50 in number, the best known of them being gold, silver, copper, iron, lead, tin, zinc, and mercury; while the non-metallic class consists of only 15, the principal of which are oxygen, hydrogen, nitrogen, carbon, sulphur, and phosphorus. Each

of these elementary substances has properties peculiar to itself; and, what is more remarkable, on each of them the Creator has stamped, in deep and indelible characters, a *particular number*, which forms, as it were, the law of its being, and determines in what proportions it shall combine with other substances. This **law of definite proportions** serves in the mineral kingdom the same end as the laws which regulate the propagation of species in the vegetable and animal kingdoms; the identity of species is rigidly preserved, and, notwithstanding the prodigious number of combinations, all confusion is avoided. Among the elementary substances only a very few enter largely into the composition of the minerals forming the earth's crust, of the oceans and atmosphere above it, or of the plants and animals that live on its surface. Indeed, only eight are of primary importance—viz., three gaseous bodies and five solids. Of the former, oxygen is by far the principal, as it constitutes nearly a half of the rocks forming the solid crust of the earth, eight-ninths of the sea, and one-fifth of the atmosphere, thus equalling the combined weight of all the other known elements. Hydrogen, again, forms one-ninth of the ocean and all other waters on the globe, besides entering largely into the composition of a great many minerals; while nitrogen forms four-fifths of the atmosphere. The five principal solid bodies are, carbon—the main ingredient in all kinds of wood, coal, and anthracite—and the oxides of iron, silicon, aluminium, and calcium, all of which enter largely into the composition of the rocky crust of the earth—the carbon and the iron forming, besides, prime essentials towards the happiness and civilisation of mankind.

Of all the elementary bodies only a few are found in nature in an uncombined state—viz. (among the metals), only gold, platinum, silver, mercury, copper, antimony, and bismuth; while of the non-metallic substances, only oxygen, nitrogen, hydrogen, carbon, and sulphur are so found. Most of the useful metals are found in chemical combination with oxygen and sulphur, or with carbon.

Density of the Earth.—Each of these elementary substances has a density or *specific gravity* peculiar to itself, ranging from hydrogen, the lightest of the gases, to osmium, the heaviest metal. In like manner, every compound body, formed by the chemical union of any two or more elements, has a specific gravity of its own, which distinguishes it from all other compounds. But the density of the earth, taken as a whole, has hitherto baffled all attempts at accurate determination. It has been estimated in three different ways: 1. By observing the attraction which a mountain exercises on the plummet, as compared with the earth's attraction on it. Of this nature were the experiments made by Maskelyne, in 1742, on the mountain Schiehallion, in Perthshire, which indicated that the density of the earth is 4.713 times that of pure water. 2. By comparing the attraction of large balls of known weight upon very small balls attached to a freely suspended bar, as compared with the attraction of the earth upon the latter. Such is the torsion-balance experiment of Cavendish, which gave a result of 5.448. Mr Baily, in 1843, repeated this experiment with great precaution, and attained a result of 5.567.

3. By observing the vibrations of a pendulum at, above, and below the surface of the earth, as also in low and high latitudes. The time in which a pendulum oscillates *varies as the square of its length*. The length of a pendulum vibrating seconds, differs considerably according as we recede from, or approach, the pole, where the attraction of the earth being at its maximum, the time of vibration is least. Thus, in the latitude of London the seconds pendulum has a length of 39.13929 inches. Such a pendulum, if transferred to any place on the equator, will be found too long to beat seconds, and too short if conveyed to either pole. The combined result of these various experiments gives to the earth a density of about 5.66 times that of water. But more reliance should be placed on the number indicated by the Great Pyramid, which in this, as in so many other great cosmical data, has anticipated modern science by more than 4000 years. It clearly and unmistakably assigns to the earth a density of 5.7 times that of pure water at the temperature of 68° Fahr., and the consequent *weight* of our planet as 6000 trillions of tons. The density of Mercury is nearly a fourth greater, that of Venus and Mars is nearly equal, while that of the sun and Jupiter is 4, Uranus 5, Neptune 6, and Saturn 8½ times less.

Internal Heat of the Earth.—As the density of the substances forming the crust of the earth rarely exceeds 2.5, which is considerably less than half its mean density, the obvious inference from the above is that the interior of our planet must consist of molten and incandescent, or perhaps of gaseous, materials, in a highly condensed state. This inference is corroborated by evidence derived from Artesian wells, mines, railway tunnels, thermal springs, geysers or intermittent springs, volcanoes, and other igneous phenomena. 1. **Artesian Wells** afford conclusive evidence that the lower we descend into the crust of the earth the temperature is found to rise. Where water from ordinary wells is scarce, it may be obtained by deep borings through the soil and underlying rock. The water thus obtained is uniformly of a higher temperature than that of the air at the surface, or even than that of ordinary springs in the neighbourhood. They are named *Artesian*, from Artois in France, where such wells have for many years been common. One such well at Grenelle, near Paris, was sunk, in 1884, to a depth of 1800 feet. The average temperature of the neighbouring wells is only 52° Fahr., whereas water derived from the Artesian well is 30° higher, or 1° Fahr. for every 60 feet of descent. A similar well at St Louis, in Missouri, has a depth of 3387 feet. Here every 65 feet of descent raises the temperature of the water 1° Fahr.,—and similar results are found everywhere. 2. The evidence from observations in **mines and deep tunnels** is to the same effect, the increase of heat downwards being constant, though greatly differing in amount in different localities. In the Mont Cenis tunnel, at a depth of 5280 feet below the summit, the increase of temperature is 1° Fahr. for every 93 feet; in the Prussian mines the average is 1° Fahr. for each 92 feet of depth; in six of the largest English mines the mean is 1° for 44 feet; while in the coal-mines of Virginia the average is 1° for 60 feet. 3. **Thermal or Hot Springs**, so numerous on the European continent,

in mountainous or volcanic regions, have frequently a temperature of 180° Fahr. 4. **Geysers**, or **Intermittent Springs**, which occur only in volcanic regions, as in Iceland, New Zealand, and the basin of the Yellow Stone River, Montana. Their action is due to the access of subterranean waters to hot rocks, producing steam, which seeks exit by conduits upward. In the Yellow Stone Park geysers are exceedingly numerous, and play at all heights up to 200 feet or more—the most remarkable being the Giant, Liberty Cap, Beehive,* and Old Faithful geysers. In the Great Geyser of Iceland, Bunsen found the temperature at the surface to be 192°, but at the depth of 72 feet it was about 260°. In fine, the average of all known observations shows a rate of increase of temperature, as we proceed downwards, of 1° for every 54 feet. The temperature of boiling water could thus be reached at a depth of less than 2 miles. But there is reason to believe that at great depths the increase is considerably slower than near the surface, and that the solid crust of the earth has a probable thickness of not less than 50 to 100 miles.

Volcanoes.—But the most decisive evidence of the intense heat of the interior of the planet is afforded by volcanoes, or burning mountains, which exist in such great numbers on the surface of the globe. The geologist can demonstrate that ever since the crust of the earth became solidified, volcanic action has existed in all ages of its history, and there is no reason for supposing that that action is now abating.

Nature of Volcanoes.—The correct idea of a volcano is to regard it as a channel of communication between the interior of the earth and its surface. Or, if we compare the earth to a mighty and intensely heated steam-boiler, then the volcano is the safety-valve which keeps the boiler from exploding,—only that besides steam the volcano ejects red-hot melted stones, or other mineral matter known as *lava*.

Shape of Volcanoes.—A volcano is usually a truncated cone, but instead of being flat atop, it presents a basin-shaped depression, known as the *crater*, at the bottom of which is the mouth of the shaft communicating with the interior. The conical form of volcanoes is due to the constant or periodic accumulation of ejected materials from the summit,† which roll down the sides of the mountain at different degrees of slope, the angle of slope being in every case dependent on the nature of the descending materials, and on their state, whether solid, viscous, or fluid. The more solid the material ejected, the more steep and pointed the form, as in Cotopaxi and Arequipa in South America; again, when the lava is viscous or semi-fluid, and alternates with ashes, the mountain is dome-shaped, as in Hecla; while, when the matter is in a highly fluid

* The "Beehive" ejects a column of water 200 feet high, and plays about once a-day; while "Old Faithful" throws up its jet 130 feet, and plays once every 65 minutes.

† Sometimes the eruptions, instead of proceeding from the summit of the cone, as in the Andean volcanoes, are mainly from the sides, as in the case of Mount Etna, which has two hundred lateral apertures from which the lava issues.

state, the sides of the volcano present very gentle slopes, as in Mauna Loa in the Sandwich Islands, the highest known.

Number of Volcanoes.—The number of volcanoes has been variously estimated. According to Humboldt there are 407, of which 225 have been active within the last 160 years. Dr Fuchs enumerates 672, of which 270 are active, while some maintain that there are 900 in the Eastern Archipelago alone.

Distribution of Volcanoes.—1. They occur either active, intermittent, or extinct, in each of the seven continents—even in Antarctica, the least known of them. To this rule Australia is no exception, as the whole extent of its eastern coast is marked by indications of former volcanic agency. 2. They are invariably found in islands, or in near proximity to the oceans and inland seas, while the interior of the continents is destitute of them. Pe-chan and Ho-chan, in the Thian Shan Mountains, and Mount Demavend in the Paropamisian range, the most striking exceptions to this rule, are only apparent, inasmuch as they all stand on the southern border of the great basin of Continental streams, which formed at one time, no doubt, a continuation of the Mediterranean, Black Sea, and Caspian. 3. Fully two-thirds of those presently active form a gigantic ring of grand natural lighthouses, encircling the **Pacific Ocean**, which, as if on account of its vastness, is further lighted up, in the centre, by some of the most remarkable volcanoes in existence (viz., those of the Sandwich Islands). Beginning at Patagonia, volcanoes occur in the entire line of the Andes and Rocky Mountains, and are thence prolonged through the Aleutian and Kurile Islands to Japan, the Philippines, New Guinea, New Hebrides, and New Zealand, down to the gigantic summits which guard the ice-bound shores of Antarctica. The distribution of volcanoes in the **Atlantic area** is somewhat similar, only that its principal beacon-lights (for the most part now extinct) are arranged in a huge curve, proceeding north and south through the centre, as in Jan Meyen, Iceland, Azores, Ascension, and St Helena; while it is only partially lit up laterally by the Madeira, Canary, and Cape de Verd groups, together with Albert volcano, in the Camaroon Mountains, on the one side, and by the West India Islands on the other. The **Indian Ocean**, of smaller dimensions, is lit up only on the western and eastern sides. In the former we need only notice Jebel Teah in Abyssinia, Kenia and Kilimandjaro in E. Africa, the Comoro Isles, Northern Madagascar, and the isles of Bourbon and Mauritius; while on the eastern side a magnificent line of volcanoes extends from the Nicobar Islands through Sumatra to Java, which last presents a greater number of burning mountains than any other country of equal extent in the world, and volcanic phenomena are often displayed on the grandest and most terrific scale.

Periodicity of Eruptions.—The eruptions of some volcanoes are continuous, such as Hecla and Stromboli; while others, as Vesuvius,* occur at irregular and sometimes prolonged intervals.

* This celebrated volcano had been in a state of activity prior to the commencement of our era, but so long before that all record of its volcanic character

Solfataras, &c.—Kindred phenomena to volcanoes are the *solfataras*, or areas where sulphurous vapours escape, and where incrustations are formed of sulphur, gypsum, and alum, as in many parts of Sicily and Italy (which supply nearly all the sulphur used in Europe for the manufacture of gunpowder); *mud volcanoes*, or *salses*, which eject hot mud, and sometimes inflammable gases, as in Java and Trinidad; and *fumaroles*, or "smoke-vents," from which gaseous fumes are emitted.

Kindred Igneous Phenomena.—Besides the foregoing, there are in various parts of all the continents, especially along their mountainous border-regions, true igneous eruptions, though they cannot be regarded as strictly volcanic, as they occur in localities remote from volcanoes. Basaltic rocks and trap-dykes are very numerous on the western side of Great Britain, especially in Cornwall, Wales, Scotland, and Ireland. The fissures for their ejection were formed by a fracturing of the earth's crust, down to a region of liquid rock, which sprang up through the fracture, and on cooling assumed the peculiar columnar, hexagonal appearance known to every one who has seen Fingal's Cave and the Giant's Causeway.

Earthquakes.—Closely connected with the internal heat of the earth are the phenomena of earthquakes. If we are to regard the earth as a globe of molten material, which in the course of ages has become surrounded by a solid crust or envelope, it is clear that, as time advances, the crust must thicken, and the interior ocean contract in dimensions. The outer crust, which was supported by the liquid sphere, must consequently in many places fall in, while in other places there will be enormous lateral pressure, resulting in flexure, or even fracture, of the strata, and in the production of mountain-chains in the line of fracture. Earthquakes are vibrations of the earth's crust, produced by a sudden movement or fracture of some of its parts. A simple example will show the true nature of an earthquake. A log of wood, smartly struck at one end with a mallet, will produce a vibratory motion along its entire mass. In the same way, an abrupt fracture of any part of the crust, along a line where the force from lateral pressure has long been increasing, may send a vibration through an entire continent or even hemisphere; and this vibration may move forward without check from the mountain-chains on the surface. Like volcanoes, they are most violent in their action along the great fractures of the earth's crust, as, for example, around the basin of the Pacific. Yet the area of

had been lost. Dense forests covered its crater, and cities and villages adorned its slopes. In A. D. 63, however, several shocks of earthquake startled the inhabitants, and suddenly, in A. D. 79, a violent eruption occurred which buried in scoriae and tufa the populous and wealthy cities of Pompeii and Herculaneum. So complete was the ruin that the very sites of these cities had become unknown, until, in 1720, they were accidentally discovered; and from subsequent excavations carried on in them, more knowledge of Roman antiquities has been obtained than from all other sources put together. From 1138 to 1631, or a period of nearly 500 years, there were only two slight eruptions; but in the latter year another tremendous explosion occurred, which lasted for three months, and destroyed many cities and villages. During the last two centuries eruptions have occurred at intervals not exceeding 10 years.

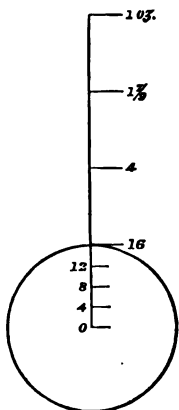
their distribution is much more extensive than that of volcanoes, there being no large region of the globe absolutely free from them. Fractures of the ground, sometimes of great extent, result from them, as also the subsidence or elevation of extensive areas of the surface, the draining of lakes, the rocking of mountains on their bases, the undulation of the ground like the waves of the sea, the overthrow of great cities, the destruction of marine life (on the same principle that a blow on the ice of a pond is often found to stun or kill the fish beneath), and finally, the generating of mighty ocean waves that extend from the shores of one continent to another, as in the case of the great earthquake of Lisbon, in 1755, when, in eight minutes, 60,000 persons were engulfed. The area of disturbance was calculated to have embraced a space four times the size of Europe, the earthquake-wave having travelled at the rate of twenty miles per minute, while at New York and the West Indies the sea rose 20 feet.

Coral-Reefs.—The cooling and contraction of the earth's crust, together with the subsidence of the sea-bottom, is demonstrated by the existence of the innumerable coral-reefs in the Pacific and Indian Oceans. From calculations made by various geologists, it appears that the rate of increase of a coral-reef does not probably exceed $\frac{1}{8}$ of an inch per year. Now some reefs are at least 2000 ft. thick, and as the reef-building polypi cannot exist below thirty fathoms, it is concluded that the base of the reef must have slowly subsided, the insects keeping pace with the movement by continually building upwards. With a very few exceptions, all *pelagic* islands in the Pacific and Indian Oceans are either of volcanic or coralline formation, or have been produced by the joint action of both. A coral island, or *atoll*, is a narrow rim of reef surrounding a shallow lagoon, with an aperture, generally on the leeward side. These reefs, though often of great depth, are never raised more than 10 or 12 ft. above the surface of the ocean. (For their soil and vegetation see below.) Coral-reefs around volcanic lands or islands are either *fringing* or *barrier*, according to their distance from the shore. The latter are often of great extent and very wide, as in the case of the Australian barrier-reef, which stretches like a broad wall along the north-eastern coast of the continent for 1200 miles, at a distance of from 20 to 60 miles from the shore, and having a depth of from 50 to 60 fathoms. Between it and the coast, ships can safely navigate, while the waves of the Pacific break against the outer edge in long lines of white foam. Each *atoll* is believed to have been at one time a *fringing reef* round an ordinary island which has slowly subsided, while the reef as slowly has increased upward, the channel between them gradually widening, until at length the island has disappeared, leaving only the circular ring of coral around a lagoon.

Gravitation, Cohesion, Chemical Affinity ; Molecules, Atoms ; the Three Conditions of Matter.

Gravitation.—Of all the mighty forces in nature, this is the grandest and the most mysterious. Its effect is to bring together bodies of matter situated far apart. Were there nothing in existence except two particles of matter, placed at rest, and millions of miles apart, this inscrutable force would instantly cause them to move towards each other in a straight line, with a velocity at first wholly imperceptible, but continually *accelerating* the nearer they approach each other, till at last it succeeds in bringing them into close juxtaposition. The operation of the force does not, however, then terminate ; it continues to act in keeping the particles together, and in imparting weight to each of them. It is this force that keeps the numerous bodies of the solar system from wandering away into space, that causes them to revolve around the sun in their grand orbits, and that doubtless connects into one harmonious whole all the countless suns and systems which people universal space. It was Newton that first gave clear expression to the law of gravitation in these words : "Every particle of matter in the universe attracts every other particle with a force directly proportional to the mass of the attracting particle, and inversely as the square of the distance between them."

The Attractive Energy which the Earth exercises on all material substances near its surface is such that, when freely suspended, they



are drawn towards it with a velocity of 16 feet in the first second of time ; *three* times 16 feet the next second ; *five* times 16 feet the third second, and so on, following the order of the odd numbers of the scale ; while the entire descent in two seconds will be 16 feet multiplied by the square of 2 ; in *three* seconds, 16 into the square of 3, &c. Comparing the Earth, in this particular, with the other planets, we find that bodies falling towards the surface of Mars descend with only a fourth of this velocity ; while in Jupiter the velocity is two and a half times greater. At great elevations above the surface the intensity of the force of gravitation decreases in the *inverse ratio of the square of the distance*. Thus, a body which (in a spring balance) weighs 16 ounces at the surface, will weigh only 4 ounces at the distance of two semi-diameters from the centre, or one semi-diameter above the surface ; at the distance of four semi-diameters it will weigh only 1

ounce, while at the distance of sixty semi-diameters (which is the Moon's distance from the Earth), it will only weigh $\frac{1}{36}$ of its weight at the surface of the Earth. Under the surface the

law of decrease is very different, it being there *directly as the distance* from the centre.* Thus, at one thousand miles below the surface the body will weigh 12 ounces; half-way towards the centre, 8 ounces; at the distance of a thousand miles from the centre, 4 ounces; while at the centre the pressure on the balance will be nothing. The accompanying diagram will render these observations more intelligible to the pupil.

Cohesion is another of the great forces of nature. It is that force which binds firmly together the different particles or molecules of a body. Gravitation brought them near each other, but then left them loose and disconnected, as grains in a heap of sand. Cohesion begins where gravitation terminates. It firmly unites and binds together the loose particles of the sand, and forms them into a compact mass of sandstone, the parts of which cannot be separated except by the blow of a hammer. In the case of the metals the particles are still more firmly united. A bar of iron cannot be bent, or broken, or twisted, and far less crushed or pulled asunder, without the application of prodigious force. Some powerful energy is thus holding all the particles together; but they have not been brought into *absolute contact*, for by cooling the bar it is found to contract both in length and thickness. But if you once succeed in breaking or crushing the bar, you will not be able to reunite the parts, *i.e.*, to re-establish the cohesion, without bringing it to a white heat, and then welding the parts together with the hammer. Cohesion is strongest in the case of solids, is very feeble between the particles of liquids, as it leaves them free to move in all directions, while in gases it is wholly absent, being replaced, indeed, by a repelling force.

Molecules and Atoms.—Cohesion is, as we have said, the force which binds together the molecules of bodies—a molecule being the smallest mass of any substance (whether simple or compound) that can exist *by itself and without decomposition*, or the smallest that can be reached by purely mechanical methods. It wholly differs in meaning from the term *atom*, which is a purely chemical term. An atom is the minutest quantity of matter which the chemist can produce, when, by his peculiar processes, he operates on molecules. The molecule is *an aggregate of atoms*, just as a body is an aggregate of molecules. The molecule has precisely the same nature as the substance of which it is a part, but the atom has not necessarily the same nature as the molecule of which it forms a constituent. Molecules may have their individuality destroyed by chemical means, but atoms are regarded as indestructible. It is now believed that an atom cannot exist in its separate or isolated state, but must either be linked with another atom of the same kind, or united with an atom of a different kind of matter: such dual atom is named a molecule. Just as our planet is the unit with which the astronomer has to deal, so the molecule is to the physicist, and the atom to the chemist.

The three conditions of Matter.—Every substance in nature is found in either the solid, liquid, or gaseous state, the particular state depending on its temperature. Some substances, such as charcoal, are as yet known only in the solid condition; others, as alcohol, in

* That is, supposing the earth to be of uniform density.

the liquid and gaseous; while by far the greater number can be made to assume any of the three states at pleasure. Of the last-named class, **water** forms a familiar example, as we see it daily in the solid state, as ice; the liquid, as water; and the gaseous, as vapour and steam. Under each of these forms the nature of its substance is not affected in the least degree, the molecules in each remaining essentially the same. The application of heat changes or wholly removes the cohesive force, and also increases the volume occupied by the water, but there is no other change. If we take a cubic inch of water, at the ordinary barometric pressure, and raise it to the boiling-point, it becomes *steam*, the volume of which, if received in a vessel, is 1800 cubic inches, or a little more than a *cubic foot*. The cubic inch of water contained a certain number of molecules, and the cubic foot of steam contains precisely the same number. From this it follows that the distance separating the molecules of the water has been increased by the heat *twelve times* in every direction. Attempts have been made by chemists to estimate the *size* of molecules by experimenting on soap-bubbles, and the result is, that in the case of water, 500 millions of them placed side by side will occupy only one lineal inch; while the number contained in a solid inch is, of course, the cube of that number!

Chemical Affinity.—Chemical affinity is that power by which bodies combine and form compounds, possessing properties wholly different from those of their constituents, such compounds being formed by the close approximation of unlike *atoms*. Thus, if a particle of sulphur be brought into contact with a particle of copper, the two, being different in nature, and possessing a strong attraction for each other, will unite and form sulphuret of copper, a body of wholly different properties from either of its constituents. For instance, sulphur is yellow and copper red, but the resulting compound is black. This is an example of what is termed **Binary Compounds**, in which two elementary substances unite and form a body of totally different qualities. A more familiar case is **water**, which is produced by the chemical union of two gases—oxygen and hydrogen (see under *Water*). *Chemical combination takes place most readily between those bodies which least resemble one another.*

The Chemical Elements.—The number of simple or elementary substances out of which the earth has been built up is 65, the metals gallium and lawesium being the last discovered. These are divided into two primary groups—metallic and non-metallic—the former containing 50 members and the latter 15, three of which, however (arsenic, selenium, and tellurium), occupy an intermediate position between the two groups. On each of these the Creator has stamped a particular and invariable number, which forms, as it were, the law of its being, and determines in what proportion it will unite with any other substance, whether simple or compound. The following table gives a complete list of the elementary bodies, together with the combining power or atomic weight of each. Those in capitals are the 15 non-metallic substances, while those in italics are the rarer metals:—

<i>Name.</i>	<i>Atomic weight.</i>	<i>Name.</i>	<i>Atomic weight.</i>
Aluminium.....	27.4	Manganese.....	55
Antimony.....	122	Mercury.....	200
ARSENIC.....	75	<i>Molybdenum</i>	96
Barium.....	137	Nickel.....	58.7
Beryllium or } Glucinum }	9.3	Niobium.....	94
Bismuth.....	210	NITROGEN.....	14
BORON.....	11	Oemium.....	199.2
BROMINE.....	80	OXYGEN.....	16
Cadmium.....	112	<i>Palladium</i>	106.6
<i>Cæsium</i>	133	PHOSPHORUS.....	31
Calcium.....	40	Platinum.....	197.5
CARBON.....	12	Potassium.....	39.1
Cerium.....	92	<i>Rhodium</i>	104.4
CHLORINE.....	35.5	<i>Rubidium</i>	85.4
Chromium.....	52.2	<i>Ruthenium</i>	104.4
Cobalt.....	58.7	SELENIUM.....	79.5
Copper.....	63.5	SILICON.....	28
<i>Dydmium</i>	95	Silver.....	108
<i>Erbium</i>	112.6	Sodium.....	23
FLUORINE.....	19	Strontium.....	87.5
Gallium.....		SULPHUR.....	32
Gold.....	197	Tantalum.....	182
HYDROGEN.....	1	TELLURIUM.....	129
<i>Indium</i>	113	<i>Thallium</i>	204
IODINE.....	127	<i>Thorium</i>	231.5
<i>Iridium</i>	198	Tin.....	118
Iron.....	56	<i>Titanium</i>	50
<i>Lanthanum</i>	92	<i>Tungsten</i>	184
<i>Lavcesium</i>		<i>Uranium</i>	240
Lead.....	207	<i>Vanadium</i>	51.3
<i>Lithium</i>	7	<i>Yttrium</i>	61.6
Magnesium.....	24	Zinc.....	65.2
		<i>Zirconium</i>	89.6

As an illustration of the foregoing table, let us suppose we wish to unite iron and oxygen gas, so as to form oxide of iron. We must take 56 grs. of iron and 16 grs. of oxygen, as the two substances will refuse to combine in any other proportion. Many substances are indeed capable of uniting with others in several proportions, but when this is the case it is invariably found that these proportions bear a very simple ratio to each other. Further, if a body A unites with several others, B, C, D, then the quantities of B, C, D, which respectively unite with A, represent also the proportion in which they will unite one with another; hence it follows that the combining quantity of a compound is the sum of the combining quantities of its components.

Motions of the Earth.—Besides accompanying the sun and planets in their mighty journey through space (p. 16), the earth has three distinct motions, each of which produces important natural phenomena.

1. **The Diurnal Motion**, or that around its own axis or polar diameter, which it performs in one solar day of 24 hours' duration; or, to speak more accurately, in one sidereal day of 23h. 56m. 4s. The circumference of the earth being nearly 25,000 miles, a man standing at any place on the equator is carried forward by this motion at the rate of wellnigh 1000 m. per hour. The sidereal day is the true time of one complete rotation of the earth on its axis, as it consists of the exact interval between two successive arrivals of the same *star* at the meridian; while the solar day is the interval between two successive arrivals of the *sun* on the meridian, and is slightly longer than the sidereal.

The best illustration of this difference is that afforded by the hands of a clock or watch. If both hands be at twelve o'clock, and then set out together from that point, the long or minute hand has made a complete revolution when it returns to 12 o'clock; but meanwhile the hour-hand has made some progress, and before it is overtaken by the long one, several minutes more will elapse. One complete revolution from 12 to 12 represents the sidereal day, while the solar day is represented by the interval between the time when the two hands were together till they occupy a similar position again. The solar day consists of two well-marked divisions, known as **day** and **night**, one half of the earth's surface being illuminated by the sun, and the other half being in darkness. Owing to the inclination of the earth's axis, the duration of sunlight at any place varies with the latitude and season of the year, being always equal to the night at the equator only. In high latitudes, day and night are equal only at the vernal and autumnal equinoxes, the day being longer than the night in summer, and shorter in winter. This difference increases with the latitude, till at the pole the sun never sets in summer. Place the school globe on the table, with its axis pointing to the pole-star. At the same level and at some distance set down a lighted candle. If you now turn round the globe with your finger, you will have an exact representation of the earth turning round on its axis, and exposing one-half its surface to the sun's rays, while the other half is in darkness. In a word, the seasons, at any given locality, depend on the varying length of the day, and this, again, depends on the inclination of the earth's axis. Were the axis perpendicular to the plane of the ecliptic, the length of the day would be always and everywhere the same, the alternation of the **seasons** wholly unknown, and the polar regions would not be covered, as they are now, with an everlasting coating of ice. Theoretically, it is possible that the inclination of the axis may have changed in the course of ages, and one of the latest and most brilliant results of modern science is that, as a matter of fact, *it has greatly and suddenly changed*. Captain H. W. Fielden, the naturalist of the late Arctic Expedition, reports:—

“Miocene beds, including a *thick seam of coal*, were found to exist as far north as lat. 81° 44', and the shales and limestones of this formation yielded abundant examples of the *flora* of that epoch; thus proving the existence, at a comparatively recent geological period, of a temperate

climate within 500 miles of the pole. Carboniferous limestone beds form the promontory of Joseph Henry. Post-pliocene beds of great thickness were found, some at a height of 1000 ft. above the sea-level, showing that *a great and rapid change in the elevation of the land must have occurred.*"

Another officer of the expedition, Mr Clements Markham, corroborates this :—

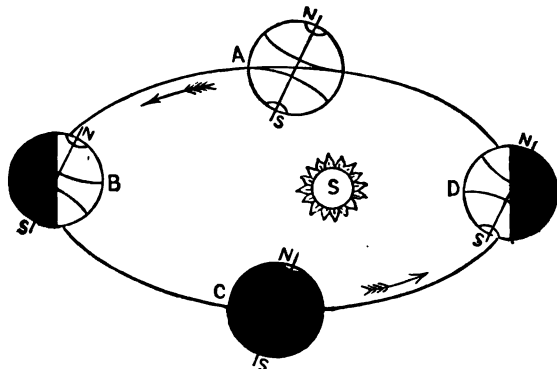
"It has long been known that at Disco, 10° further south, there had been, in a comparatively recent geological period, forests growing with 50 or 60 different species of *arborescent trees, some evergreen, though mostly deciduous.* The Expedition discovered excellent tertiary coal in 82° N., and brought back impressions of leaves, showing that luxuriant forests had once grown so near the pole as that. The wonder did not stop there; for unless there had been such *a change in the axis of the earth as astronomers declare to be impossible,* those forests must have been exposed to a darkness extending to 140 days out of the year. . . . Other explorers had discovered wood in the now frozen regions of Banks Land and Prince Patrick's Island, *with the bark on,* and which evidently had *grown where it was found,* showing how *extremely rapid* must have been the *changes of climate* which had taken place over the polar area."

The sacred volume declares that in the days of Noah the whole world was inundated by a flood, which covered the highest mountains, and that, with the exception of one family, the entire human race was destroyed. A **change in the inclination of the earth's axis** would certainly produce such a catastrophe—a catastrophe which was accompanied with direful results to all future generations: the alternations of heat and cold became so rapid as to affect the longevity of man, which has from that date gradually shortened from nearly a thousand years to threescore years and ten.

2. The Annual or Orbital Motion, caused by the revolution of the earth round the sun.—As the earth rotates on its axis about 365½ times during one revolution round the sun, such is the number of days in the year. The common or calendar year, for convenience' sake, is made to consist of only 365 days, but the tropical or equinoctial year, which consists of the interval between two returns of the sun to the equinox of any given place, contains 365 days, 5 hours, 48 minutes, 50 seconds. The odd hours would soon accumulate to a serious extent, and gradually push the seasons forward, until, at length, they would no longer correspond with the changes of annual temperature. To prevent this inconvenience, the odd hours, which amount nearly to the quarter of a day, are allowed to accumulate till they amount to 24, and are then got rid of by adding a day to February, the shortest month, thus making every fourth year a *leap year*—*i.e.*, to consist of 366 days. The excess of the tropical year, however, over the calendar, comes short of six hours by 11 minutes, 10 seconds. This difference, again, would in the course of ages become serious, as it amounts to a day in 135 years. To remedy this, every *hundredth* year is regarded as a common year, except the *fourth* hundred, which is counted a leap year.

The axis of the earth, it must be remembered, is not at right

angles to the plane of the orbit, but makes an angle of $23^{\circ} 28'$ with the perpendicular. The axis, moreover, remains parallel to itself during the entire revolution, its extremities or poles ever pointing to the same fixed stars. It is in virtue of this arrangement, as simple as it is beautiful, that the alternations of the seasons are produced, together with the ever-varying length of the day and night.



The Four Seasons.

In the annexed diagram S represents the sun in one of the foci of the earth's elliptical orbit; A B C D the position of the earth in spring, summer, autumn, and winter; N S the polar axis of the earth, constantly pointing northward; the arrow, the direction of the earth's motion; while the shaded portion indicates the part that is not illuminated by the sun. Thus, at the vernal equinox, A, the sun's rays, owing to the earth's rotation on her axis, fall daily on every part of the earth's surface, from pole to pole, the day being everywhere 12 hours long and equal to the night. As the earth advances from A to B, the sun constantly shines on the entire space enclosed by the Arctic circle, where, accordingly, there is no night at midsummer, while the Antarctic circle is in darkness for an equal time. During the progress of the earth from A to B, the days have been increasing in length in the northern hemisphere, and decreasing in the southern. But the longer the day the greater is the amount of heat derived from the sun. His rays, moreover, fall more vertically on the northern hemisphere at this season than in winter, and these two causes more than compensate for the sun's greater distance from the earth in summer than in winter. Without continuing this description further, we need only observe that the earth is at A on March 21 (the vernal equinox); at B on June 21 (the summer solstice); at C on September 21 (the autumnal equinox); and at D on December 21 (the winter solstice).

3. The Secular or Precessional Motion.—Notwithstanding what has been stated above, the earth's axis does not remain *absolutely* parallel to itself, nor point precisely to the same star. In reality, it

oscillates slowly on its own centre, its extremities forming two small circles in the heavens. This movement, called the Precession of the Equinoxes, is caused by the attraction of the sun and moon on the equatorial regions, or bulging portion of the earth : and the effect of it is that the equinoctial points, or the points where the ecliptic crosses the equator, move westward about 50" every year, and therefore, in the course of ages, winter will be where summer is now. At present the axis points almost exactly to the bright star *Polaris* in Ursa Minor, but in B.C. 2170 (or 4046 years ago) *Alpha Draconis* was the pole star, being then situated on the meridian, and $3^{\circ} 42'$ beneath the pole ; while *Alcyone*, the brightest star in the Pleiades, was crossing the meridian above the pole, at a point high up in the sky, near the celestial equator. This combination cannot recur for 25,868 years. Such is the period of the **Precession of the Equinoxes**—a period in which the earth's polar axis effects one complete gyration, and is the grandest cycle of time known to man.

Revolution of the Apsides.—But the mighty precessional cycle above described is shortened by being combined with another motion, caused by the attraction of the planets, and called the *Revolution of the Apsides* (from *apsis*, a curve). The Apsides are the points in the earth's orbit at which she is nearest to and furthest from the sun, the former being called her *perihelion*, and the latter her *aphelion*. The line connecting these points, which corresponds with the major axis of the earth's orbit, is called the *line of the Apsides*. From the cause above assigned, this line is not continually directed towards the same points in the heavens, but slowly revolves, and the result of the combination of this revolution with the precession of the equinoxes causes the cycle of the seasons to be performed in about 21,000 years, instead of 25,868 years.

MATHEMATICAL DIVISIONS OF THE EARTH.—In order to describe with precision the position of places on the earth's surface, and the effects that result from its orbital and diurnal motions, certain imaginary lines are drawn round it, which are called *great circles* when they divide it into two equal hemispheres, and *small circles* when they divide it unequally.

The **Great Circles** are the Equator, Ecliptic, the two Colures, Meridians, and Horizon.

The **Equator**, a large circle, equidistant from the poles, divides the earth into a Northern and a Southern Hemisphere. The latitude of places is measured from it, north and south ; and their longitude on it, east and west.

The **Ecliptic** is a great circle, which represents the sun's apparent annual track among the fixed stars, or it is the path through the heavens which the earth would appear to describe if seen from the sun. It derives its name from being the circle on or near which the moon must be in the case of an *eclipse*. Its plane makes an angle of $23\frac{1}{2}^{\circ}$ with the plane of the equator. The sun is in the north, or highest point of the Ecliptic, on 21st June ; and he is then

vertical at the tropic of Cancer; he is in the south, or lowest point, on 21st December, and is then vertical at the tropic of Capricorn. The Ecliptic is divided into twelve equal parts, called **signs**, of 30° each, named from the constellations or groups of stars through which the sun appears successively to pass. These, with the days on which the sun enters them, are as follows:—

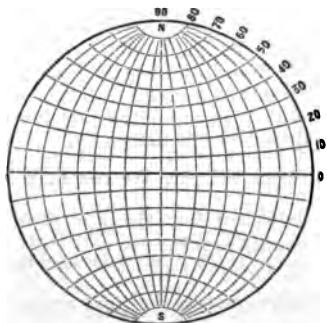
Aries, March 21.	} <i>Spring.</i>	Libra, Sep. 23.	} <i>Autumn.</i>
Taurus, April 19.		Scorpio, Oct. 23.	
Gemini, May 21.		Sagittarius, Nov. 22.	
Cancer, June 21.	} <i>Summer.</i>	Capricornus, Dec. 22.	} <i>Winter.</i>
Leo, July 22.		Aquarius, Jan. 20.	
Virgo, Aug. 23.		Pisces, Feb. 19.	

The **Nodes** (*nodus*, a knot) are the two points where a planet's orbit cuts the plane of the Ecliptic. The *line of the nodes* is that which joins the two nodes. The Ascending Node is the point at which a planet crosses to the north of the plane of the Ecliptic, while the Descending Node is that in which the planet crosses to the south of that plane.

The **Colures** are two meridians which divide the Ecliptic into four equal parts, making the four Seasons of the year. One of them intersects the equinoctial points, Aries and Libra, and is thence called the Equinoctial Colure; the other intersects the solstitial points Cancer and Capricorn, and is called the Solstitial Colure.

The **Meridians**, or lines of longitude, are great circles passing through the poles, and cutting the equator at right angles. Each of them divides the earth into two hemispheres, which, in respect to each other, may be termed east and west. There are 12 meridians commonly drawn on globes, each 15° apart, equal to a difference in time of one hour; and 18 meridians on maps of the world, each 10°

apart, corresponding to a difference in time of 40 minutes. But every place is supposed to have a meridian passing through it; and when the sun comes to that meridian, it is noon or mid-day at that place. The **longitude** of a place is its distance east or west from the **prime meridian**, or that one from which we agree to count. This has varied with different nations: thus the French reckon from Paris; the Germans from Ferro, one of the Canary Islands; the Americans from Washington (though at sea, as a matter of convenience, they count from Greenwich, which is 77° east of Washington); and the English from Greenwich. But there is one meridian which has a claim above all others to be regarded as the first—viz., that passing



Parallels and Meridians.

Greenwich, which is 77° east of Washington); and the English from Greenwich. But there is one meridian which has a claim above all others to be regarded as the first—viz., that passing

through the Great Pyramid of Jeezeh, latitude 30° north, and longitude $31^{\circ} 9'$ east. Every meridian divides the globe into two equal hemispheres; but this meridian, contrary to all others, divides equally all the land surface, and traverses a greater extent of land than any other. When the latitude and longitude of a place are known, its exact position on the globe may at once be pointed out. Thus, if I read in the newspapers that a ship in which I am interested was spoken at sea, in latitude 40° north, I could never find out the place on a map, as there are thousands of places which have that latitude; but if the information is added that it was in longitude 27° west, I learn at once that the exact spot was in the Atlantic Ocean, and very near the Azores. But how does the captain of the vessel know his exact position on the globe when out of sight of land, and how does he always know the direction in which he is sailing? The first question is easily answered, provided the sky is clear and the heavenly bodies visible. He knows that the sun is due south at noon, and the *sextant* at once enables him to determine the moment when the sun comes to the meridian. If the sun has sunk beneath the horizon, the pole star is an equally sure guide for all vessels sailing in the northern hemisphere, as it is very nearly due north at all hours of the day and night. A sight of this star enables the captain to ascertain his exact latitude. If, for example, the star is 50° above the horizon, then the *latitude* of the ship is also 50° . This being determined, he next proceeds to find out his *longitude*. At mid-day he glances at his watch, or at the ship's chronometer, each of which is carefully set to Greenwich time. Suppose his watch, instead of twelve o'clock (*which is the real time there*) indicates three o'clock, then, if he is sailing westward, he knows that his longitude is 45° west. Thus having determined both his parallel and meridian, he knows the ship's true position, for it is at the point where these two lines intersect. Should, however, the sky be obscured with clouds for a considerable length of time, he has to depend almost exclusively on the information derivable from the log-line and the ship's compass. The former shows the speed of the ship since the last astronomical observation was taken, and the latter the direction in which she has been sailing (see under *Mariner's Compass*). The value of a degree of longitude varies according to the latitude, and is nowhere equal to a degree of latitude except on the equator. At 60° N. or S. a degree of longitude is equal to 30 geographical miles, or half its length on the equator; while at the poles it vanishes to nothing.

The **Horizon** separates the visible half of the celestial concave from the half that is invisible, and is either *rational* or *sensible*. The rational, or true horizon, by which the rising and setting of all the heavenly bodies are determined, is an imaginary plane passing through the centre of the earth, and prolonged in imagination till it attains the region of the stars. Parallel to it, and coextensive with it, is the sensible horizon, whose plane is a tangent to the surface at the point on which the spectator is placed. These two planes, although separated throughout their whole extent by a semi-diameter

of the earth, will yet, on account of the vast distance at which that interval is seen, be confounded together, and appear as one line in the heavens. As applied to the earth, however, the sensible or apparent horizon is the small circle which terminates our view of the surface, where earth and sky appear to meet. It enlarges or contracts, according as the spectator's eye is elevated or depressed: thus, if the eye be elevated 6 feet above the sea, the circular expanse of water visible to it will be 3 miles in diameter. The **Cardinal Points** of the horizon are north, south, east, and west; the **Zenith** is the upper pole of our horizon, and the **Nadir** the lower pole.

The **Small Circles** are the Tropics, the Parallels of Latitude, and the Polar Circles.

The **Tropics** are two small circles parallel to the equator, and at the distance of $23\frac{1}{2}^{\circ}$, north and south. They are so named because the sun, arrived at them in his apparent annual course, seems to *turn away*, either northward or southward, as the case may be. The northern is called the Tropic of Cancer, and the southern the Tropic of Capricorn, because they touch the ecliptic in the beginning of those signs.

The **Parallels of Latitude** are small circles parallel to the equator, the object of which is to indicate the latitude of places, and to connect together all places on the globe having the same latitude. Though on globes and maps of the world they are usually drawn at intervals of 10° , every place is supposed to have a parallel of latitude passing through it (see under *Meridians*).

The **Polar Circles** are two small circles, drawn around the North and South Poles respectively—the former being called the Arctic, and the latter the Antarctic Circle. Their distance from the Poles is $23\frac{1}{2}^{\circ}$, that being the angle formed by the earth's axis and a line drawn perpendicular to the earth's orbit. When the sun is vertical to places situated on the Tropic of Cancer, his rays extend beyond the Pole to the Arctic Circle, and all countries within the Antarctic Circle are then in darkness.

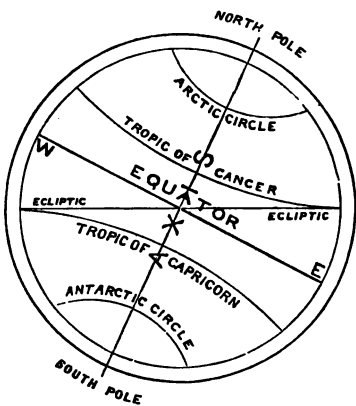
Zones.—The Tropics and Polar Circles divide the surface of the earth into five great Climatal Zones or Belts—viz.:

1. The **Torrid Zone**, 47° in breadth, or $23\frac{1}{2}^{\circ}$ on either side of the equator, and bounded by the Tropics of Cancer and Capricorn. Every place in this wide region has the sun vertical to it twice a-year; and as the sun's rays never fall very obliquely on any part of it, the temperature at the surface of the earth is here always very high.

2. Two **Temperate Zones**, one northern and the other southern, each 43° in breadth, lying between the Tropics and the Polar Circles. Never having the sun vertical, they are characterised by a lower temperature than tropical regions; the fruits of the earth are less luxuriant and spontaneous; and man, compelled to exercise his cor-

poreal and thinking powers, attains to a higher degree of intelligence and civilisation than in those regions where his wants are supplied without any exertion on his part.

3. The Two **Frigid Zones**, each $23\frac{1}{2}^{\circ}$ in radius, are included within the Polar Circles. They are deprived of the influence of the sun for long intervals in winter, and have a correspondingly greater length of day in summer, when his rays fall very obliquely on the surface. These conditions, coupled with the extreme cold of the long winters, are so unfavourable to human culture and human happiness, that the tribes who inhabit the frigid zone have not been able to attain to any considerable degree of civilisation (see p. 30).



IV.—CONFIGURATION OF THE SURFACE.

The terraqueous globe must be supposed to have assumed its present spheroidal form when rotating in its primitive incandescent state. This form the vast collection of waters now on its surface powerfully tends to perpetuate—*first*, by their capacity of yielding to the centrifugal force arising from the planet's rotatory motion; and, *secondly*, by their filling up innumerable depressions in its crust—depressions which, it is now ascertained, nearly equal in depth the highest elevations of the land. These elevations nowhere amount to more than $\frac{1}{4}$ part of the radius, and therefore scarcely interfere with the regular form of the planet. In fact, the mountain-chains on the globe produce no greater deviation from its spheroidal shape than the small protuberances on the rind of an orange do on its general form.

Division into Land and Water.—The surface of the earth, which, as we have already seen, comprises an area of 197,000,000 square miles, is very unequally divided into land and water. The total area of the land is estimated at 52,000,000 sq. m., or a little more than $\frac{1}{4}$ of the entire surface; while the waters cover 145,000,000 sq. m., or nearly $\frac{3}{4}$ of the whole (the exact ratio is as 1 : 2.854). The land is, moreover, very unequally distributed over the surface: thus,

the northern hemisphere contains three times as much land as the southern; the eastern hemisphere, or Old World, contains twice as much as the western; and if a great circle be drawn round the globe, having London as its centre, it will divide the surface in such a way as that nearly all the land will be in one hemisphere—which may



therefore be called the *continental hemisphere*; while the other, or that which has Antipodes Island, near New Zealand, as its centre, will be nearly all water, and may therefore be called the *oceanic hemisphere*—only that it contains Australia and a portion of South America. If we regard the earth as divided into zones instead of hemispheres, we find that the North Temperate Zone, or that in which the continent of Europe is situated, is the one which contains the greatest proportion of land.

Continents.—The land surface of the globe is further broken up into huge masses, called continents, which are six in number—viz., Europe, Asia, Africa, North America, South America, and Australia; but should the land around the South Pole turn out to be a continent, the number will be seven. These, however, are not always detached from each other, but collected into groups, the members of which are generally united by isthmuses. Properly speaking, there are only three continents—viz., *first*, the Old World, containing Europe, Asia, and Africa; *second*, the New World, embracing North and South America; and *third*, the Australian continent—the only important mass of land in the oceanic hemisphere, with the exception of the recently-discovered countries within the Antarctic Circle. Of these grand continents the eastern or Old World is by far the largest and most important, having an area of 31,840,000 sq. m., a maritime coast-line of 68,000 m., and a pop. of 1,274,000,000. The area of the western continent, or New World, is 15,798,000 sq. m., being almost exactly $\frac{1}{2}$ of the former; its pop. 86,000,000, or $\frac{1}{14}$ of the Old World; while its coast-line is only 36,000 m., or but little more than $\frac{1}{2}$ of the Old World. Australia (with Tasmania) has an area estimated at 3,000,000 sq. m., being $\frac{1}{10}$ of the western continent, and a population of 1,600,000, or $\frac{1}{80}$ of America.

The Old and New Worlds compared.—The following are some of the comparisons, equally interesting and curious, that have been drawn by Carl Ritter and other geographers between the two great continents, in respect to their forms of *contour* and *relief* or their horizontal and vertical projection:—

Contour.—1. The greatest length of the Old World is from east to west, while that of the New is from north to south; in other words, the eastern continent has its greatest extension in the direction of the *parallels*, while the western has its greatest extension in the direction of the *meridians*.

2. The greatest extension of both continents towards the north and south is nearly under the same meridians. Thus, the Cape of Good Hope is nearly on the same meridian with Cape Nordkyn in Norway; the peninsula of Malacca with Cape Severo in Siberia; and Cape Horn with the north-west angle of Greenland (which, however, is now known to be detached from the northern continent).

3. Both continents attain their greatest extension from west to east along the same parallel—viz., that of 50° N.

4. Both continents spread out widely towards the north, where they closely approach each other; both are abruptly terminated by the Arctic Ocean in nearly the same latitude—viz., that of 72°; whereas toward the south they widely diverge, and narrow down to single promontories.

5. In either continent a large portion of the area is nearly detached from its principal mass; thus Africa is nearly severed from the one continent, and South America from the other.

6. All the great peninsulas of both continents follow a southerly direction; as the Scandinavian, Spanish, Italian, Hellenic peninsulas, Africa, Arabia, Hindustan, Further India, Corea, and Kamtschatka, in the one; and California, South America, Florida, and Nova Scotia, in the other. The only important exceptions to this generalisation are Jutland in the Old World, Yucatan and Boothia Felix in the New, which stretch *northward*; with Anatolia in the former, and Alaska in the latter, which project towards the *west*.

7. The opposite coasts of the two grand continents are strikingly conformable to each other, the projections of the one being opposite to the indentations of the other, though separated by the breadth of the Atlantic: thus Brazil stands opposite to the Gulf of Guinea; Western Africa to the Gulf of Mexico; and Nova Scotia to the Bay of Biscay.

8. Comparing the two continents in another way, we find that Africa with Madagascar has its counterpart in South America with the Falkland Isles; while Florida and the West Indies have a similar correspondence with Malacca and the East Indian Archipelago.

9. Taking the six separate continents, it is a remarkable fact that, with the exception of Africa, they all present to the ocean on their northern sides broad flats of low-lying land; while their southern extremities are rocky, pointed, and elevated. Again, while Africa, South America, and, we may almost add, North America, contract toward the south into single promontories, each of the others sends

out three separate projections, which curiously correspond, each to each. Thus, the Spanish peninsula resembles Arabia; Italy with Sicily corresponds to India with Ceylon; and the Hellenic peninsula, with its adjacent islands, to Further India with the Malay Archipelago.

10. But the most important feature of configuration is that which has reference to their comparative lengths of *coast-line*. While the three southern continents present to the ocean an almost unbroken outline, neither receiving its waters into their bosoms nor projecting into it any important peninsulas, the three northern ones are highly indented, though in very different degrees, their masses evincing a tendency to break up into members. Thus, Asia and North America has each an extensive line of coast, while Europe has wholly surrendered herself to the ocean, as if conscious that, at a future time, that element would become one of the chief sources of her prosperity.

Vertical Relief.—In regard to the lines of vertical relief, on the other hand, the following are the most important generalisations:—

1. All the continents rise gradually from the sea-shore towards the interior, where they attain their maximum elevation; and thus each of them presents to the surrounding ocean two great slopes, which greatly differ, however, in length and degree of inclination.

2. In the Old World, the long gentle slope is inclined toward the north, and the short abrupt slope toward the south; while in the New World the gentle slope is toward the east, and the abrupt toward the west, in each case the abrupt slope facing the larger ocean.

3. But while each of the grand continents has thus a law peculiar to itself, it is also influenced by the law of the other. Thus, though in the Old World the long or gentle slope is toward the north, and the short or abrupt one toward the south, it is also true that the slope fronting the east is more gradual than that fronting the west. In like manner, though in the New World the longer slope fronts the east, and the shorter the west, it is also true that the slope which fronts the north is gentler than that which fronts the south.

4. The elevated ridge formed by the intersection of the great slopes or *watersheds* is usually occupied by lofty mountain-chains, and constitutes the grand *water-partings* of the different continents. Hence in the Old World the general direction of the principal mountain-ranges is from east to west, but in the New it is from north to south; while in both they extend in the direction of the *greatest length* of the continents. Thus, in the eastern continent, one immense mountain-chain extends, with few interruptions, from the western extremity of the Pyrenees to the vicinity of Behring Strait; while in the western, an almost unbroken range extends from the north-east angle of Alaska to the southern extremity of Patagonia.

5. This law holds equally true in regard to all the more important peninsulas and islands. Thus Scandinavia, Italy, Malacca, Corea, Kamtschatka, and Lower California, together with Great Britain, Corsica, Sardinia, Sicily, Crete, Madagascar, Sumatra, Java, Japan, Cuba, Hayti, Jamaica, and New Zealand, are all traversed by mountain-ranges in the direction of their greatest lengths.

6. While in both hemispheres the reliefs go on increasing from the Polar Circles to the Tropics, the highest elevations of the eastern hemisphere occur in the vicinity of the Tropic of Cancer, and in the western they are found midway between the equator and the Tropic of Capricorn: compare the positions of Mount Everest, in the Himalaya, with that of Sorata, in the Andes.

7. A remarkable similarity exists between Europe and Asia in respect to their reliefs. Thus the Pyrenees and Alps correspond with the Taurus, Caucasus, and Himalayan ranges; the basin of the lower Danube has its counterpart in Tonquin; European Turkey corresponds with Further India; the valley of the Po with the basin of the Ganges; while Delhi, Calcutta, and Bombay at once suggest Milan, Venice, and Genoa.

8. Notwithstanding the imposing height of the various mountain-chains, the mean elevation of the continents depends far less on this than on the configuration and extent of the plains and table-lands. For example, if the material of the Alps were spread over Europe, its surface would only be raised 22 ft.; while, on the contrary, were the great plateau of Spain, which has an elevation of only 2250 ft., distributed in a similar manner over the continent, the general surface would be raised 76 ft.

9. Taking each of the continents separately, the average elevation of Europe would be 670 ft.; North America, 748 ft.; South America, 1132 ft.; Asia, 1150 ft.; Africa, probably 1600 ft.; and Australia, perhaps 500 ft.; and it is estimated that if all the inequalities of the earth's surface were reduced to a uniform natural level, the land would have an elevation above the sea-level of 925 ft. If these data could be relied on, the real level of the earth's surface, as distinguished from that of the sea, could be approximately estimated at 230 ft. higher than the present sea-level.

Origin of the Continents.—The existing continents and islands are of comparatively recent origin, and they must not be regarded as having the same antiquity as the earth itself. Modern research puts it beyond all doubt that, in former ages, all those wide areas now occupied by the continents formed portions of the bed of the ocean. The petrified remains of marine plants and animals in the very heart of each of the continents, and in the rocks forming the summits of the loftiest mountain-chains, were there no other proof, put this startling fact beyond all dispute. Hence the question arises, Has, then, the ocean sunk below its ancient level, leaving great portions of its bed dry? or have parts of the sea-bottom been in some places upheaved by earthquakes and other volcanic agency, while by the same agency, in other instances, the dry land has been depressed? The earlier geologists entertained the former view, being of opinion that the sea must have gradually sunk down, and by some unexplained means entered the earth's crust; or that it had, in part, become actually annihilated! But even were these

extravagant suppositions conceded, they would go but a small way in explaining the phenomena of the present distribution of sea and land. All geologists are now agreed that the volume of the ocean has ever remained the same; that its general level has never materially altered; that the existing lands have been repeatedly submerged beneath the sea, and as frequently raised again above its surface; that this process of alternate elevation and depression has taken place in our own country, and is, indeed, going on at the present moment before our eyes—for example, the raised beaches so prevalent in many parts of Scotland; the gradual but well-ascertained upheaval of the land in certain parts of Sweden, the plains of Patagonia, and the pampas of Buenos Ayres; while the slow subsidence of the western coast of Greenland has been demonstrated by Dr Pingel, the Danish naturalist, to have been going on for the last 400 years. Moreover, wherever circular coral islands or barrier-reefs abound, Mr Darwin has shown that there is a slow and continual sinking of the sea-bottom. The existing contour and relief of the continents are doubtless due to the same causes as those which have served to elevate them above the ocean-level. Before their upheaval, they no doubt presented inequalities somewhat similar to those which they now do; for the existing bed of the ocean is far from being uniformly level, some parts being only a few feet beneath the surface, while others are several thousand fathoms. We cannot, however, imagine that when the great masses of the land rose above the sea-level the forces that upheaved them ceased to operate. In many parts of the world the general level of large areas of the surface has been slowly and silently elevated, while in others it has been in like manner depressed.

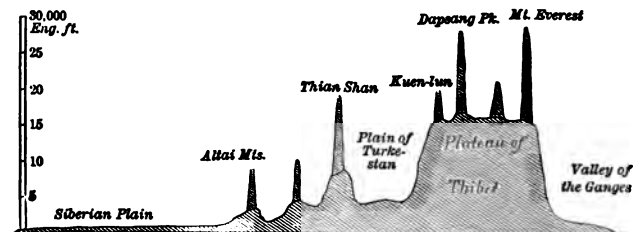
Mountain-systems.—Thus lofty mountain-chains, generally regarded as the most unchanging objects in nature, have attained their present dimensions by gradual accessions of altitude and by forces continued throughout many ages. Owing to the very important part which mountain-chains perform in the climate and natural history of the globe, their exact position and direction on the earth's surface, and the reason why they have such position and direction, are questions of the deepest interest. A full and satisfactory answer cannot as yet be given to these questions; but some interesting facts bearing on them may be regarded as approximately established. 1. Mountains are rarely seen existing as isolated masses, but generally in a long series of elevations, arranged in the same line, such series being denominated a *chain* or *range*. 2. It is generally found that one range is closely connected with one or more ranges near it, and running in a parallel direction. These form a *system*. 3. Sometimes the chain remains single, but sends out several branches or spurs at right angles to itself. 4. The nucleus or central mass of the chain

generally consists of granite or some other igneous rock which has been protruded from below, and clearly indicates both the nature and direction of the internal force. 5. By carefully inspecting an orographical map of the globe, it will be seen that the various mountain-systems occupy portions of **great circles** of the globe—such circles being the lines in which the internal force meets with the least resistance. 6. Mountain-chains of the same geological formation are believed to be of the same antiquity; and, however widely separate, are parallel to one another. 7. The relative, though not the absolute, age of a mountain-chain may be ascertained from the mineral character of the strata forming it, and the fossils, if any, found imbedded in them. Thus it may be easily determined whether any given chain belongs to the Plutonic, Hypozoic, Palæozoic, Secondary, Tertiary, or Post-tertiary era (see diagram "Succession of Life").

There are only two really great mountain-systems in the world, the one in Asia-Europe, extending from the Spanish peninsula to Behring St., or a distance of 9000 miles; and the other in North and South America, extending along its western coast from Point Barrow in Alaska, to Cape Horn in Patagonia, and having a total length of about 10,000 miles. The Bolor Tagh range, in the centre of Turkestan, and midway between Novaia Zemlia and Ceylon, is the great nucleus from which all the mountain-ranges of the Old World diverge. This primary chain, or central knot of mountains, stands on the lofty plateau of Pamir (itself 15,600 ft. high), between the sources of the Amoo and the Yarkand, and attains an elevation of 19,000 ft. In considering the mountain-systems of this gigantic continent, it will be observed that the entire north-west of Asia, embracing the greater part of Siberia and W. Turkestan, consists of an immense lowland plain of about twice the size of Europe. The remainder of the continent is, with few exceptions, occupied with two vast table-lands of triangular shape—an eastern and a western—which meet together in the Bolor Tagh Mountains; the larger triangle having its base resting on the Pacific Ocean, and the smaller on the Levant and Red Sea. The first, which is known as "Eastern High Asia," has its central parts occupied with the vast rainless desert of Shâmo; while the second is subdivided into the minor table-lands of Iran, Arabia, and Asia Minor. The principal mountain-ranges of the Old World either form the bounding-walls of these lofty plateaux or traverse their interior.

Mountain-ranges of the Eastern Triangle.—1. *The Himalaya* ("abode of snow"), between India and Tibet, forming the southern wall of the triangle, extends from the Bolor Tagh to the great bend of the Brahmaputra, beyond which it branches off into the lower ranges of China and Further India. This chain contains the loftiest elevations on the earth's surface; is 1500 m. long, and from 100 to 350 m. broad; height of snow-line on the south side, 16,200 ft., on the north side, 18,600 ft.; highest elevation at which wheat grows, 13,000 ft. on the south side, but on the north side, according to Captain Gerard, 18,544 ft. The three loftiest peaks are—Mt. Everest or Gaurisankar, 29,002 ft. above the level of the sea (the culminat-

ing point of Asia, and probably the highest summit on the earth's surface); Kunchinjunga, 28,150 ft.; and Dhawalagiri, 28,080 ft. Several other peaks in this range rise to an elevation of 25,000 ft., and not fewer than a hundred attain a height of 20,000 ft., while the average height of the whole chain equals that of Mt. Blanc, the loftiest European mountain.



Section of Asia, from north to south.

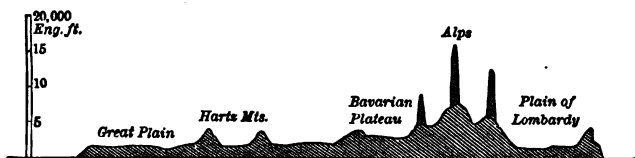
2. The North-eastern System, or the chains forming the northern wall of the triangle, and extending in an E.N.E. direction from the Bolor Tagh to Behring St. It embraces, 1. The *Thian Shan* or Celestial Mts., in Kashgaria, separating the basins of the Obi and Yarkand; h. s., Tengri-Tagh, 21,000 ft. 2. The *Altai* and *Sayansk*, in southern Siberia, separating the basin of the Amoor from those of the Yenisei and Lena; h. s., Mt. Katunsk, in the Altai, 12,790 ft. 3. The *Stanovoi* and *Aldan Mts.*, in eastern Siberia, between the Arctic Ocean and Sea of Okhotsk; h. s., Kliutschew, 15,825 ft. This and many other summits are active volcanoes.

3. Chains traversing the Interior of the Eastern Triangle—1. The *Karakorum* and *Kuen-lun Mts.* in Tibet, separating the upper basins of the Indus and Brahmaputra from that of the Yarkand; h. s., Dapsang Peak, in the Karakorum, 28,278 ft.; height of snow-line, 20,000 ft. 2. The *Pe-ling*, *Yun-ling*, and *Nan-ling*, in China; h. s., 12,000 ft. 3. *In-shan* and *Khin-gan*, south-east of the desert of Shamo.

Ranges flanking the Western Triangle.—1. The chains that skirt the southern side of this triangle have no great elevation—viz., the *Suliman* and *Hala Mts.*, separating India from Afghanistan and Biluchistan, and *Jebel Akhdar*, in the south-east of Arabia; h. s., Takht-i-Suliman, 11,301 ft. 2. The chains flanking the western side are—*Jebel Hedjaz*, on the west co. of Arabia; Mount Horeb, 8526 ft., in the desert of Sinai; Hermon, in Palestine, 9053 ft.; and the Lebanon range, along the co. of Syria, 10,061 ft. 3. The ranges forming the northern wall of the triangle are—(1.) the *Hindu Kush*, separating the Panjab and Afghanistan from Turkestan; h. s., 20,000 ft. (2.) The *Paropamisan*, separating Western Turkestan from the plateau of Iran; h. s., Koh-i-Baba, 16,000 ft. (3.) The *Elburz*, south of the Caspian, and separating its basin from that of the Euphrates;

h. s., Mt. Demavend, 18,464 ft. (4.) The *Mts. of Armenia*, bet. the basins of the Caspian and Black Sea; h. s., Mt. Ararat, 17,112 ft. (5.) The *Taurus* and *Anti-Taurus* ranges, enclosing the table-land of Asia Minor; h. s., Mt. Argish, 13,000 ft. (For the Caucasus see below, p. 46.)

European Mts.—Proceeding still further west into Europe, we find that the entire east and centre of that continent consists of an immense low-lying plain, extending from the Urals to the Carpathians, and from Mt. Caucasus to the Arctic Ocean; while south of the Baltic it stretches west as far as the shore of the North Sea. But southern Europe, which is highly mountainous, embraces the seven following chains, all of which are to be regarded as a western continuation of the Asiatic Mountains. 1. **The Balkans**, in the Hellenic Peninsula,



Section of Europe, from north to south.

separating the basin of the Danube from the Adriatic and Ægean Seas; h. s., Tchar Dag, 9840 ft., and Mt. Olympus, 9749 ft.; height of snow-line on the latter, 9000 ft. 2. **The Carpathians**, separating the valley of the Danube from the Gt. Eastern Plateau; h. s., Mt. Botschetje, 9528 ft.; height of snow-line, 6000 ft. 3. **The Alps Proper**, a huge crescent-shaped range, chiefly in Switzerland, but extending from Vienna to Nice, and separating the upper basins of the Danube, Po, Rhine, and Rhone. The Swiss Alps consist of three principal ranges. (1.) The *Bernese Alps*, between the Aar and Upper Rhone; h. s., Finster Aar Horn, 14,100 ft. high, and the Jungfrau, 13,718 ft. (2.) The *Lepontine* or *Helvetian Alps*, forming the basins of the Rhine, Rhone, and Po; h. s., the Simplon, 11,510 ft. high, and Mt. St Gothard, 10,900 ft. high. (3.) The *Pennine Alps*, further west, between the basins of the Rhone and Po, containing Mt. Blanc, in Savoy, the loftiest summit of the Alps, and (since 1860) the culminating point of France, 15,781 ft. high; Great St Bernard, 11,080 ft.; Mt. Cervin or the Matter Horn, 14,705 ft.; and Monte Rosa (the culminating point of Switzerland, 15,217 ft. high. Height of snow-line in the Swiss Alps, 8000 ft. 4. **The Apennines**, 800 m. long, traverse the entire length of Italy, reappearing in the island of Sicily, and forming the water-parting between the Mediterranean and Adriatic; h. s., Mt. Etna, in Sicily, 10,874 ft.; Monte Corno, in the north of Naples, 9521 ft.; height of snow-line, 9500 ft. 5. **The Sardo-Corsican System**, in the islands of Corsica and Sardinia; h. s., Monte Rotondo, 9068 ft. 6. **The Gallo-Francia Mts.**, embracing all the mountains of

France between the Garonne and Rhone, and connected with the Alps Proper by the Jura chain, besides which there are four separate ranges—viz., the *Vooges*, *Cote d'Or*, *Auvergne*, and *Cevennes Mts.*; h. s., Mont Molleson, in the Jura chain, 4690 ft. high. 7. **The Hesperian System**, occupying the whole of the Spanish peninsula, and forming five distinct ranges—the two loftiest being the Pyrenees, in the north, separating the basin of the Garonne and Bay of Biscay from those of the Ebro and Douro; h. s., Maladetta, 11,168 ft. high; and the Sierra Nevada, in the south, between the basins of the Guadalquivir and Mediterranean; h. s., Cerro Mulhacen, 11,663 ft. Height of snow-line in the Sierra Nevada, 11,200 ft.

Besides the seven great ranges, all of which are more or less connected with each other, and form a continuation of the Asiatic Mts., we have the following five detached systems—viz., the British, Scandinavian, Sarmatian, Uralian, Caucasian. 1. **The British System** traverses the British Archipelago from the Scilly Isles to Shetland, a distance of 800 m. As compared with some of the other systems of Europe, it is of very moderate elevation, and nowhere reaches the line of perennial snow, though Ben Nevis, its culminating point, probably comes short of it by less than 400 ft. The principal chains are: (1.) *The Grampians*, in Scotland, crossing the country in its widest part, and separating the Highlands from the Lowlands; h. s., Ben Nevis, 4406 ft. (2.) *The Mts. of England*, extending from the Cheviots, on the Scottish border, along the west coast to Cornwall; h. s., Snowdon, in Wales, 3590 ft. (3.) *The Irish Mts.*, forming a circular ring round the island; h. s., Carran Tual, in Kerry, 3414 ft. 2. **The Scandinavian System**, in Sweden and Norway, traversing the peninsula for 1150 m. in its greatest length, from the Naze to the North Cape, and separating the Atlantic basin from the great European plain. It is usually divided into three sections—viz., *Hardanger Field*, *Dovre Field*, and *Kiolen*; h. s., Skageloeistinden, 8670 ft.; height of snow-line, 5000 ft. 3. **The Sarmatian System**, in the centre of the great European plain, though attaining to no great elevation, is of importance as forming the water-parting between the Baltic, Black, and Caspian Seas. The *Valdai Hills*, at the source of the Volga, are 1100 ft. high. 4. **The Uralian System**, forming the boundary between Europe and Asia, and the water-parting between the extensive basins of the Volga and Petchora, and that of the Obi. Total length, including the Mts. of Novaia Zemlia, 1680 m. They consist of round-backed, plateau-shaped masses of very moderate elevation, nowhere attaining to the limit of perennial congelation; h. s., Konjakofsky, on the 60th parallel, 5397 ft. 5. **The Caucasian System**, which may be regarded as forming a connecting link between the Carpathians and mountains of Armenia. They extend in one immense chain, 750 m. long, from the Black Sea to the Caspian, and separate the great European plain from the depressed valley of the Kur. Mean elevation from 8000 to 9000 ft.; h. s., Mt. Elburz, 18,571 ft., being 2790 ft. higher than Mt. Blanc; height of snow-line, 11,000 ft.; limit of the cereals, 7000 ft.

African Mountains.—The continent of Africa is really a peninsula stretching south-westward from Asia-Europe; but as it remains to a great extent unexplored, its mountain-systems cannot be very accurately defined. The northern half of the continent is an oval, and the southern a triangle; the latter being, in general, twice the elevation of the former, while the mountains skirt the margins of these two figures. 1. **The Atlas Mts.**, in the N.W., consist of three ranges running parallel to the coast, and to the Hesperian Mts., with which they are geologically connected, and from which they are separated by the narrow Strait of Gibraltar. They may be regarded as a continuation of the mountains of Sicily, extending from Cape Bon, in Tunis, to Cape Ghir on the Atlantic coast, and forming the water-parting bet. the Mediterranean and Sahara. They are supposed to attain an elevation of 13,000 ft.; h. s. ascertained, Mt. Miltin, in Morocco, 11,400 ft. 2. **The Kong Mts.**, in the S.W. of the oval, separating the basin of the Niger from the Gulf of Guinea. Average elevation, 2000 ft.; h. s., Mt. Rennell, 3200 ft. Still further east, Mts. Alantika and Mindif reach 9000 and 6000 ft. respectively, beyond which the country remains unexplored. 3. **Mts. of Abyssinia**, which run north and south for about 30 degrees, and may be regarded as a continuation of the Lebanon range, through the desert of Sinai. They separate the basin of the Nile on the W. from the Red Sea and Indian Ocean on the E.; h. s., Ras Detschen, 15,986 ft. 4. Proceeding to the peninsular portion of the continent, we find an immense **coast-range** skirting the E. side of the triangle, from the equator to the Cape of Good Hope (parallel to which are the Madagascar Mts.), and forming the boundary wall of the South African plateau; h. s., the volcanic peaks of Kilimandjaro and Kenia, 20,065 and 18,000 ft. respectively, near the equator; Lupata Mts., from 8000 to 10,000 ft., at the mouth of the Zambezi; Drakensberg, in Natal, 10,357 ft. 5. The ranges skirting the W. side of the triangle, from the Cape of Good Hope to the Bight of Biafra; h. s., Table Mt., 3582, Omatako Berg, 8739 ft., and the Camaroon Mts., which attain in Albert volcano 13,000 ft. 6. West of the great lakes are the **Blue Mts.**, which, according to Sir Samuel Baker, are 9500 ft. in elevation.

Mountain-systems of the New World.—In each continent of the New World the main axis extends unbroken through the entire length, close to the W. coast, while a secondary axis is near the E. shore—all of them lying in *great circles* of the globe, as do those of the Old World. Vast low plains occupy the interior of both continents, but the plains on their seaward slopes are only of limited extent. The western side of N. America, from Behring St. to the Isthmus of Panama, consists of a broad elevated plateau, surmounted by two lofty mountain-ranges, which attain their greatest elevations where the plateau is widest—viz.:

1. **The Rocky Mt. Range**, forming the eastern wall of the plateau, and extending from the Arctic Ocean to Central America; h. s., Mt. Brown, 15,990 ft., and Mt. Hooker, 15,700 ft., at the sources of the Saskatchewan, and forming the loftiest summits of British North

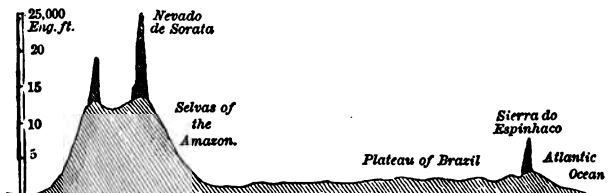
America; Freemont's Peak, 13,569 ft., Long's Peak, 12,000 ft., and Bighorn, 10,000 ft., in the U.S.; Orizaba, 17,347 ft., and Popocatepetl, 17,884 ft., in Mexico, next to St Elias, the h. s. of this continent. Agua, in Guatemala, 13,000 ft., h. s. of Central America. **2. The Pacific Range**, on the W. margin of the plateau, extending from Alaska to the S. extremity of Old California, and known as the *Sea Alps* in the N., the *Cascade Mts.* in the centre, and the *Sierra Nevada* in the S., embrace the following mountains: Mt. St Elias, 17,900 ft., and Mt. Fairweather, 14,782 ft., on the coast of Alaska;



North America, from west to east.

Mt. St Helens, N. of the Columbia, 15,750 ft., the h. s. of the U.S.; Mt. Hood and Mt. Jefferson, 15,500 ft., S. of the Columbia. **3.** On the E. side of North America are the **Alleghanies or Appalachian Chain** in the E. of the U.S., extending from Labrador to the Gulf of Mexico; h. s., Black Mt., in N. Carolina, 6707 ft.

In S. America the W. highland is a long, narrow plateau surmounted by two gigantic mountain-chains, named the **Andes**, in many respects the most majestic system of mountains on the surface of the globe, though its h. s. do not equal those of the Himalayas. The following are amongst the most celebrated of the Andes: (1.) **Andes of Quito**, extending from the Caribbean Sea to the 5th degree of S. lat.; h. s., Chimborazo, 21,424 ft., Cotopaxi, 18,875 ft., Antisana, 19,137 ft. (2.) **Andes of Peru**, from 5° to 14° S.; Knot of Huanuco



South America, from west to east.

and Pasco, 11,800; Nevada de Sasaguanca, 17,904 ft. (3.) **Andes of Bolivia**, from lat. 14° to 21° S.; Sorata, 24,812 ft., the loftiest summit of the Andes and of the New World. Chuquibamba, 21,000 ft., Illimani, 21,150 ft. (4.) **Andes of Chile**, from lat. 21° to 42° S.; Aconcagua, near Valparaiso, 23,910 ft. The highest and most continuous ranges forming the secondary axis of the continent, extend

along the E. coast, reaching their greatest elevation west of Rio Janeiro. Their average altitude is from 4000 to 6000 ft., the highest peaks reaching nearly 10,000 ft.

Australian Mts.—The mountain-system of Australia may be regarded as forming a distant continuation of those of S.E. Asia, through the Malay peninsula and the double chain of large islands forming the Eastern Archipelago. A series of ranges skirt the coasts, but all of moderate elevation, the only well-defined chain being that along the E. side, stretching from C. Melville to Bass Str.; h. s., Mt. Kosciusko, in the Victorian Alps, 7308 ft. In New Zealand a chain of snow-clad mts. traverses the two larger islands from N. to S., and parallel to the Mts. of Australia, attaining their greatest elevation in S. Island, where Mt. Cook and Mt. Tyndall reach 13,200 and 11,000 ft. respectively; h. s. in N. Island, the volcanic peak of Mt. Egmont, 8838 ft.

Table-lands and Plains.—These do not differ essentially, except in regard to elevation. The table-lands or plateaux (Fr. *plateau*, a flat dish) are merely lofty plains intimately associated with mountain-ranges, of which indeed they form the bases. Extensive tracts of country that are over 1000 ft. in altitude are called plateaux. They occur chiefly in the Old World, while the New is mainly characterised by its immense low-lying plains. About one-half of the surface of Asia is occupied with an immense table-land, extending without interruption for about, 5500 m. from the Mediterranean and Red Seas in the W. to Corea in the E., with a breadth varying from 2000 to 700 miles.

It embraces the following portions: plateaux of Asia Minor, Armenia, Arabia, and Iran, in the W.; plateau of Pamir, 15,600 ft. high, the loftiest table-land on the globe, and containing the Sir-i-Kol, the highest known lake, and the plateau of Tibet, of about equal elevation, originating all the great rivers of S. and S.E. Asia, in the centre; plateau of Gobi or Shamo, an immense rainless desert of shifting sand, containing no vegetation, 4000 ft. high, 1200 m. long, and from 500 to 700 m. broad, in the E.; plateaux of Malwa, Dakhan, and Maisûr, in Hindustan. The principal table-lands of Europe are the Swiss plateau, plateaux of Spain, 2250 ft. high; Langre, Orleans, and Auvergne, in France; plateau of Bavaria, 1660 ft. The only plateaux of great elevation in N. Africa are those of Morocco and Abyssinia, each of which is surmounted by lofty mountain-ranges; while the triangular portion of the continent forms an immense moderately-elevated table-land, the Victoria Nyanza Lake having an elevation of 3740 ft., and Lake Tanganyika, 2710 ft. In the New World a series of lofty table-lands forms a broad, irregular belt along the coast of the Pacific, from Behring Str. to the Caribbean Sea, and from the latter to the Str. of Magellan. In N. America its elevation increases from 800 ft., near the Arctic shores, to 8000 ft. in the table-land of Mexico. An E. highland of much less extent stretches from Hudson Str., in Labrador, to the north of Alabama, but nowhere exceeding 2000 ft. In the southern continent the W. highland is a long narrow plateau, attaining in Bolivia

a height of 12,900 ft. ; while the E. or secondary highland, known as the plateau of Brazil, is about 2500 ft. in elevation. In the Old World one vast and uniformly level plain, the **Great Northern Plain**, extends with but one important interruption (the Ural Mts.) from the shores of the Atlantic to the vicinity of Behring Str., and from the Arctic Ocean to the Caucasus and Altai Mts. It extends over 190° of lon., and embraces an area of 4½ million sq. m. The European portion of it consists of the **German Plain**, stretching from the Str. of Dover to the Vistula, and the **Sarmatian Plain**, between that river and the Urals; while the Asiatic portion is known as the **Siberian Plain** and **Kirghiz Steppes** (in some parts 83 ft. below the sea-level—for example, the Caspian Sea, the largest lake in the world). In Africa, the vast sandy desert region of the **Sahara**, extending from the Atlantic to Egypt, long supposed to be a deeply depressed plain, is now ascertained to have a general elevation of 1500 ft. Of a somewhat similar character, but of a much lower elevation, is the whole **interior of Australia**, supposed by some to be the bed of a sea of recent date, a conjecture which is borne out by its immense number of salt lakes. Of the Minor Plains of the Old World, the principal are—the **Plain of Lombardy**, watered by the Po; **Hungarian and Wallachian Plains**, in the basin of the Danube; **Mesopotamia**, or lower basin of Euphrates and Tigris; the **Thur**, or valley of the Indus; **Plain of Hindustan**, or valley of the Ganges; **Indo-Chinese Plain**, in Further India; and the **Chinese Plain**, or lower basin of the Yangtse and Hoang-ho. The plains of the New World occupy a still larger portion of the entire area. The principal are: 1. The **Great Central Plain** of N. America, extending from the Arctic Ocean to the G. of Mexico, and from the Alleghanies to the Rocky Mountains; it is watered by many great rivers, embraces the largest fresh-water lakes on the globe, and is traversed from east to west by a broad, gentle swell of land, which divides the waters that flow to the Arctic Ocean from those that enter the G. of Mexico. 2. The **Atlantic Plain**, between the Alleghanies and the Atlantic Ocean. The central region of S. America is chiefly a vast alluvial and extremely level plain, having scarcely any distinguishable water-parting, and destitute of great lakes. It comprises the basins of the Amazon, Orinoco, and Rio de la Plata, called respectively *Selvas*, *Llanos*, and *Pampas*. *Selvas* or *Slivas* are the low-lying forests bordering the Amazon. They are extremely dense, and are 1500 m. long and about 600 m. broad. For several months annually this region is under water, and the natives have to resort to the tree-tops. *Llanos* form one of the most level portions of the earth's surface; they are grassy flats, almost destitute of trees, often inundated by the Orinoco, and at other times parched up by drought. Here frequent conflagrations destroy every living thing. **Pampas** are the immense plains in the basin of the Parana and Uruguay; they are treeless, but many parts of them afford admirable pasture to troops of wild horses and cattle, while others are for the greater part of the year quite sterile.

Prairies are the boundless meadow-lands which occupy fully

3,000,000 sq. m. in the centre of N. America ; they are destitute of trees, but are covered with tall grass, gay with wild flowers, and alive with herds of wild cattle. East of them, towards the Alleghanies, hundreds of miles of unbroken forest exist. On the west side of the Mississippi the prairies are called plains.

Tundras are swampy desert tracts along the north of Russia and Siberia. They are covered with peat, and in winter are frozen to a great depth.

Steppes are sandy, barren, and not unfrequently saline tracts, surrounding the Caspian and Sea of Aral, and stretching far into Siberia. For some months annually they are covered with long rough grass (which is, however, burnt up by the heat and drought of summer), while in winter they are howling wastes of snow.

Landes are a low-lying, sandy, and monotonous district of France, stretching eastward from the Bay of Biscay, and producing nothing but heath and furze.

THE OCEANS.—About 145,000,000 square miles, or nearly three-fourths of the entire superficies of the globe, are permanently covered with water, the surface of which forms a true *natural level*, all the parts of which are nearly equidistant from the earth's centre. Such a level, in the case of a rotating body like the earth, the materials of which were once capable of yielding to the influences of gravity and of the other forces that acted upon it, is of a spheroidal form, like that of an orange, and differs materially from a dead, horizontal level, such as the floor of an apartment. The surface of lakes, deserts, plains, and even of the continents, conforms itself to this natural level ; it forms the limit from which all the elevations of the land and the soundings of the ocean are measured ; and, in constructing a canal or railway along the surface, an allowance must always be made for this difference, amounting to about eight inches in the mile. Unlike the continents, which are separated from each other by natural barriers, all the great waters of the globe are continuous and united, and hence, though there are three great continents, there is, strictly speaking, but one ocean, all the parts of which are in free and constant communication. This interchange and circulation of its waters is a grand modifier of climate—one which powerfully contributes to the salubrity of the continents and the intercourse of nations (see under "Climate"). Still, the great land-masses are so arranged on the surface of the globe as to divide the waters into seven vast sheets, called *oceans*, corresponding to the seven continents specified in p. 38. These are the Atlantic, Pacific, Indian, Arctic, and Antarctic Oceans—each of the first two being divided by the equator into two nearly equal parts.

Depth.—Contrary to all former ideas, the average depth of the ocean does not exceed 2000 fathoms, or rather more than

two miles; while the maximum depth, so far as known, is 27,450 ft. (see below, pp. 57, 59). One great feature is common to all the oceans—viz., that the narrow fringe of water along the seaboard has only a depth of a few hundred feet; but the descent then becomes abruptly precipitous to a depth of from 10,000 to 12,000 ft. This feature is well illustrated at the entrance of the British Channel, where the distance between a depth of 600 ft. and 12,000 ft. is in some places only ten miles.

Temperature.—The surface temperature varies with the latitude and season of the year, but, except in the neighbourhood of ice, it is everywhere warmer than lower down. After a depth of 100 fathoms (at which seasonal changes have no effect), the temperature invariably decreases as the depth increases, until we arrive at a depth of 2000 fathoms, where, as a rule, it remains stationary at, or always very near, 35° Fahr.

Animal Life.—By the investigations of H.M.S. Porcupine, in 1869, and the still more protracted researches of the Challenger,* it is now found that animals of many orders and genera—some of them, too, of very high organisation—exist at the profoundest depths of the ocean. Sponges, annelids, molluscs, echinoderms, and crustaceans, have already been found in vast numbers. It appears that life is sustained even in the most depressed and coldest regions of the sea-bottom; while in those areas equivalent in depth below the sea-level to that of Mont Blanc above it, animal life abundantly prevails. Other regions apparently form the sepulchral resting-places of organisms which, when living, existed near the surface. Thus geological formations, stamped with the permanency of ages, appear in these regions to be in course of construction. In short, life and death, reproduction and decay, are active in all depths hitherto attained.

Saltiness.—The waters of the ocean are salt and bitter, their density varying according to the quantity of saline matter they contain. Generally speaking, the quantity of salt is from 3.5 to 4.0 per cent of the entire volume; though near the mouths of great rivers, and in the polar regions during the melting of the ice, the surface-water is considerably fresher. In other localities, such as confined seas which receive no important rivers, and in the regions swept by the trade-winds, owing to excessive evaporation, the quantity of saline matter is somewhat more.

* The celebrated Challenger Expedition, which has so largely contributed to our knowledge of the ocean, returned to Spithead on May 23, 1876, after an absence of 3½ years. During this voyage the ship sailed or steamed over 68,000 miles, and took about 400 deep-sea soundings. Of these, 2 were over 4000 fathoms, 9 between 3000 and 4000, 168 between 2000 and 3000, 124 between 2000 and 1000, and 97 below 1000 fathoms. A rough average gives 1758 fathoms, or 10,410 feet. This depth is less than one-half of that formerly supposed.

All the substances which are found on the land, and which cold water can hold in solution, occur in the ocean. No fewer than 28 ingredients are enumerated by Forchhammer as contributing to its saltiness, but less than half this number exist in any appreciable quantity. Of these, sodic chloride (common salt) is by far the principal, after which come magnesian chloride, magnesian sulphate, calcic sulphate, calcic carbonate, and silica. The last three play an important part in furnishing the coatings of molluscs, coral insects, and silicious infusoria. The original cause of the saltiness of the ocean is perhaps an insoluble problem. It appears to have existed ever since the planet had an ocean, or at least ever since the ocean became the home of living creatures—for the geologist can show that the fossil fauna of the globe consists largely of species that must have lived in salt water. At the same time, when we reflect that all the rivers in the world are more or less impregnated with the very same saline ingredients as we find in the ocean, that they nearly all discharge themselves into the sea, and that in the process of evaporation *fresh* water alone enters into the gaseous form, it seems to follow that the saltiness of the ocean is gradually increasing. This slow increase may account for the otherwise inexplicable fact that frequently since the ocean became inhabited, its varied population became wholly, or almost wholly, extinguished.

Density.—The density of sea-water of the average degree of saltiness, as compared with pure water, is as 1.0275 to 1, both being at 62° Fahr. The salt and increased density tend to preserve the liquid condition of the sea at low temperatures, and also render it less vaporisable than fresh water. Fresh water freezes at 32° Fahr., but sea-water only at 28½° (or if the water be undisturbed, as low as 25° 4). Accordingly, except in the polar regions, the surface of the ocean is very rarely covered with ice.

Movements of the Ocean.—The waters of the ocean are subject to various kinds of motion, arising from the attraction of the sun and moon, the impelling influence of the winds, and from temperature.

1. The attraction of the moon, sometimes aided and sometimes impeded by that of the sun, produces the grand phenomenon of the **Tides**, which, from the astronomical point of view, have been already treated of (p. 11). The great tidal wave may be regarded as originating in the South Pacific and Antarctic Oceans, its progress being less interfered with there by the proximity of land; though, theoretically, the undulation extends from pole to pole, its centre and highest part being always right under the moon, whose progress in the heavens it

closely follows. Were the globe entirely covered with water, the wave would move round the earth in 24 hours, being at the rate of 1000 miles per hour in equatorial regions. Its speed and direction, however, are greatly interfered with by the continents and islands which it meets in its westerly course. The consequence is, that in many places high tide lags far behind the moon. Having crossed the Indian Ocean in six hours, it enters the Atlantic, and pursuing a northerly course at a velocity of from 500 to 700 miles an hour (its central part being far in advance of the extremities, which are obstructed by the margins of Africa and South America), it arrives at Brest and the west of Ireland; and reaching the Orkneys and Bergen at the same time, it proceeds southward through the North Sea, arriving at Aberdeen in 37 hours, and the mouth of the Thames in 49 hours, from the time it left the antipodes. Lines connecting any two places on the opposite shores of a sea or ocean having high tide at the same time are termed *co-tidal lines*, and are of great use in navigation. The height of the tidal wave in the free expanse of the Pacific does not exceed 2 or 3 feet; in the Atlantic and Indian Oceans 8 or 9 feet; but in bays and gulfs, open at the mouth and narrowing towards the interior—as, for example, the Bay of Bengal, Bristol Channel, Solway Firth, and Bay of Fundy—it rises to 30, 40, or even 70 feet. Where such gulfs terminate in river estuaries, the tide advances up the river with great impetuosity and speed, when it is called a *Bore*. Striking cases of this occur in the Severn, Hughly, and Amazon. At Bristol, the spring tide rises 40 feet, and a bore 9 feet high rushes up the Severn with its tributaries. In the Hughly it is often 25 ft.; while during the equinoxes, in the Amazon, no fewer than five distinct bores are seen pursuing each other for 200 miles up the river, with a height of from 12 to 15 ft.

2. *Wind-waves*.—When the air is still, or when the wind is very gentle, the surface of the ocean is unruffled, and smooth as a mirror. But should the wind become a little stronger, a certain amount of friction takes place between the atmosphere and the ocean, a gentle ripple is generated on the surface of the latter, moving in the direction of the wind. Should the velocity of the wind still further increase, *waves* and even *billows* are formed, which may attain to gigantic dimensions. The highest waves known to the mariner are found off the Cape of Good Hope and Cape Horn, where they sometimes attain to an altitude of from 30 to 40 ft. Here, as also in the Bay of Biscay, large ships may be separated by an interval of only a few hundred feet, and yet for an instant wholly lose sight of each other. In the North Sea, owing to the shallow

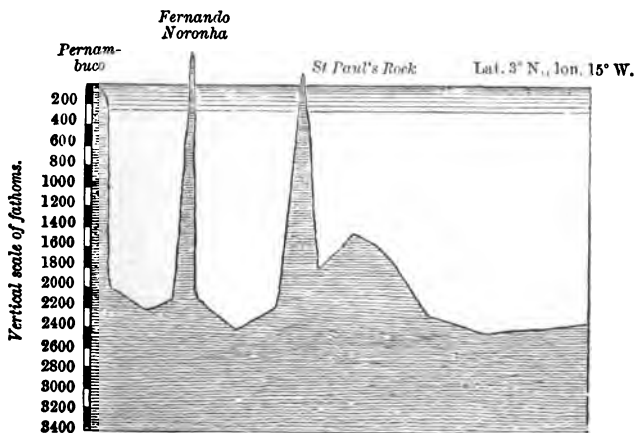
ness of the water, the height of the waves seldom exceeds 9 ft. Whatever the strength of the wind, or the height of the waves, it is believed that the agitation of the water does not penetrate to any great depth; but that the deeper the sea the greater the velocity of the waves. When we speak of the velocity of waves, we do not mean that the water of which a wave is formed moves from one place to another. The water oscillates or moves up and down, but does not advance, nor has the wave any *transporting* power, as may be shown by throwing a cork on the surface. During a gale it is indeed violently agitated, but makes no headway, its position relative to a fixed object on land remaining absolutely stationary. Who has not seen the action of the breeze on a field of corn or grass, and noticed the beautiful undulations, which keep pace with the wind, advancing in a few seconds from one extremity of the field to the other? But no one supposes that a single stalk has left its original place. Close to shore, however, when during a tempest the waves dash against the rocks with extreme violence, the momentum is so great that immense masses of stone or concrete, sometimes weighing 40 tons, are torn from their position in piers or breakwaters, and carried along several feet, or even broken to pieces.

3. Ocean Currents.—On his voyage to distant lands the navigator not unfrequently encounters immense rivers of heated waters flowing through the comparatively cool and motionless water of the ocean; while sometimes the moving stream has a much lower temperature than the rest of the sea. These are called *Ocean Currents*, and exist in all the great oceans. Sometimes they have a great velocity, are hundreds of miles in width, and thousands of feet in depth. Nor are they confined to the upper stratum of the ocean, for usually when a warm, light surface-current is flowing in one direction, another current of denser and cooler water can be discovered moving in the opposite direction along the bed of the sea. By these counter-currents a vast system of oceanic circulation is established over the entire globe, somewhat analogous to the circulation of the blood in animals by the veins and arteries. Not only are the waters of the ocean kept from stagnating by these currents, but the climate and terrestrial life (whether animal or vegetable) of the continents are powerfully modified by them. The causes of these vast movements are mainly three—viz., heat, gravitation, and the action of the winds blowing incessantly in the same direction. In regard to heat and gravitation, it is only necessary to remark that the rays of the sun in tropical and temperate regions raise the temperature of the surface-waters, expand them, cause them to ascend and flow

away to a cooler region, their place becoming occupied by colder water coming from beneath. On the other hand, the high temperature of the tropics greatly promotes evaporation—a process by which the surface-water is converted into aqueous vapour. It is only fresh water, however, that thus passes into the gaseous form, and therefore the longer evaporation proceeds, the saltier becomes the remainder of the surface-water. It therefore becomes denser or heavier, and must consequently descend, in order to maintain the necessary equilibrium, its place becoming occupied by fresher water from beneath. As the former action produced two horizontal currents, one on the surface, and the other along the sea-bottom, so this produces two vertical currents, one from the surface, downwards, and the other from below, upwards. By referring to the article “Trade-winds” (p. 77), it will be seen that these unvarying winds prevail on both sides of the equator to a little beyond either tropic, and that their direction is towards the west, or contrary to that of the earth’s rotation. Their action on the water being constant, they generate a surface-current of the ocean in their own direction, forming what is called the Equatorial current, which, in each of the three great oceans, flows in a westerly direction with a breadth of nearly 50°. On reaching the eastern shores of either of the great continents, the Equatorial current separates into two branches, one going northward and the other southward. Let it be further borne in mind that there is a vast difference between the temperatures of polar and equatorial seas—that the cold waters of the former, being the heavier, tend constantly to flow into the warmer waters of the latter, while these in return, being thus displaced, flow away as surface-currents to the poles. The polar and return currents, were they acted upon by no external force, would move in the line of the meridians. They are deflected, however, from this course, by the increasing action of the earth’s rotation. Thus the polar currents (*i.e.*, currents from the N. or S. pole), as they advance, tend more and more towards the *west*, and the return or warm currents, towards the *east*. But these directions are modified by the forms of the continents, and the prevailing character of the winds which they encounter on their way. It is a useful rule to remember that all currents, owing to the rotation of the earth, tend to their own right. For a description of the individual currents, see below, under the different oceans.

The **Atlantic Ocean** deserves the first place, for though less than half the size of the Pacific, it is the best known to Europeans; and of all the great waters of the globe it has always been the most important, as that on whose shores and gulfs the greater number of the civilised nations of the earth have taken up their abode. It

occupies a huge, angular, canal-shaped basin, whose sides are nearly parallel to each other — the projections of the one side standing opposite to the indentations of the other; extends from N. to S. about 9000 miles; separates the Old World, on the east side, from the New on the west; and connects the Arctic with the Antarctic Ocean. It varies greatly in breadth in different parts, being 4100 miles between the shores of Morocco and the Isthmus of Florida; 1700 miles between Brazil and Sierra Leone; and 900 miles between Greenland and the coast of Norway. The area is estimated at 35,000,000 square miles, or nearly half the area of the Pacific. It is distinguished from all the other oceans by the fewness of its islands, by the great number of seas and gulfs which it projects into the continents that confine its waters, and by the vast extent of land which is drained by the rivers that flow into it. Its land basin is calculated at 19 million sq. miles, or more than double the area drained by the Pacific, though the Atlantic itself is not half the size of the latter. Owing to the marginal position of the Andes and Rocky Mts., it is calculated that about six-sevenths of the entire drainage of both Americas find their way to the Atlantic; while from Europe it receives every important river except the Volga, and from Africa all except the Zambezé. Putting aside the older soundings as utterly untrustworthy, its average depth, as ascertained by the Challenger Expedition of 1872-76, is about 2500 fathoms, or 15,000 ft. In the North Atlantic it rarely exceeds 2000 fathoms, though, near St Thomas, one sounding of 3875 fathoms was obtained, while in another part the



Section of Equatorial Atlantic.

Challenger found a depth of 3916 fathoms, or 23,500 ft., which is now to be regarded as the greatest known depth of this ocean. A sub-

marine plateau runs N. and S. near the middle, with an average depth of water of less than 2000 fathoms; but on either side of it, and S. of the equator, it generally exceeds 3000 fathoms. Of this plateau the Azores may be regarded as the culmination and centre, for it extends from the tropic of Cancer to lat. 50° N., where it joins the so-called "Telegraphic Plateau," which extends from the coast of Ireland to that of Newfoundland, and on which are laid the submarine cables connecting the European and American continents. The temperature of the water at 2000 fathoms deep is uniformly 35° Fahr. But in the S.W. Atlantic, owing to a tongue of cold water from the Antarctic Seas, the bottom temperature varies from 31° to 33½° Fahr.

The principal Branches of the Atlantic are the Baltic, the North Sea, the Irish Sea, the English Channel, the Bay of Biscay, the Mediterranean, and the Gulf of Guinea, on the east side; and Hudson Bay, Gulf of St Lawrence, Gulf of Mexico, and the Caribbean Sea, on the west. The principal Islands and Archipelagos are Iceland, the British Isles, Azores, Madeira, Canary and Cape Verde Isles, near its eastern shores; and Newfoundland, Cape Breton, Bermudas, Bahamas, Antilles, and the Falkland Isles, near its western. Its chief Affluents from the Old World are the Neva, Rhine, Loire, Tagus, Rhone, Po, Danube, and Don; Nile, Senegal, Niger, Congo, and Orange: and from the New World the St Lawrence, Mississippi, and Rio Grande del Norte; the Orinoco, Amazon, and Rio de la Plata. Among its principal Currents are the Equatorial current, which flows from the Gulf of Guinea (under the influence of the constant trade-winds) to Cape St Roque, the N.E. angle of S. America, where it is divided into two branches—the one called the Brazilian current, flowing southward, and the other north-westward to the Caribbean Sea, with a velocity of 18 miles per day at the surface, but at the bottom (which, according to Captain Nares, is 50 fathoms deep), at only half that velocity, its surface being about 75° Fahr.; and the far more celebrated Gulf Stream, which, leaving the G. of Mexico, flows through the Str. of Florida with an average velocity of 48 miles a-day, and a mean temperature of 81° Fahr. "After having run 3000 miles towards the north, it still preserves, even in winter, the heat of summer. With this temperature it crosses the 40th degree of north latitude, and there overflowing its liquid banks, it spreads itself out for thousands of square leagues over the cold waters around, and covers the ocean with a mantle of warmth that serves so much to mitigate in Europe the rigours of winter. Moving now more slowly, but dispensing its genial influences more freely, it finally meets the British Islands. By these it is divided, one part going into the polar basin of Spitzbergen, the other entering the Bay of Biscay, but each with a warmth considerably above the ocean temperature." The Trade-winds blow regularly in its intertropical regions; but beyond these limits the winds are variable. Thus we see that the waters of the Atlantic between the equator and the 40th parallel are kept in a perpetual whirlpool, the circumference of which cannot be less than from eleven to twelve

thousand miles. In the centre of this revolving current there is a mass of nearly stagnant water, covered by dense masses of an ever-green sea-weed called *Fucus natans*, which made so lively an impression on the mind of Columbus and his crew when about to discover America in 1492.

The Pacific Ocean separates America on the east from Asia, Malaysia, and Australia on the west; and is by far the grandest expanse of water on the globe, having an area estimated at 72,000,000 square miles, or equal to one-half the entire waters of the globe. Unlike the Atlantic, of which it is fully double the size, its greatest length is from E. to W. along the equator—a direction in which it extends 175°, or upwards of 12,000 miles, reckoning from the coast of Peru to the Malay peninsula. Its greatest breadth, between Behring Strait and the Antarctic Circle, is 9000 miles, corresponding with the extreme length of the Atlantic. In shape, the Pacific is somewhat oval, being widest in the middle, broadly open at the south, but nearly closed at the north, where the opposite shores are only 36 miles apart. Its extent, compact form, and the direction of its greatest elongation, make it the counterpart of Asia—Europe, the dominant mass of land on the globe. The greatest depth recorded by the Challenger Expedition, in 1875, was north of Papua, lat. 11° 23' N., lon. 143° 16' E., where they found 4575 fathoms, or 27,450 ft., being upwards of five miles. This is, therefore, the greatest depth of the sea, as presently known to science. The depth increases slowly from south to north, the mean difference between the depth of the South Pacific and that of the North being perhaps as much as 1000 fathoms—the average depth of the latter being about 3000 fathoms. This expedition also ascertained that at the depth of 500 fathoms the temperature is uniformly about 45° Fahr., while below that depth it falls to 37°, 36°, 34°, and sometimes even to 32°. The Pacific Ocean was unknown to Europeans till the year 1513, when it was discovered by Vasco Nunez de Bilbao, from the summit of a mountain near the Isthmus of Panama. Magalhaens, who sailed from America to the Philippine Islands, in 1521, bestowed on it the name of Pacific, in consequence of the calm and delightful weather he experienced while navigating its surface.

The coast-line on the American side, though bold, is very little indented by the ocean, the principal Inlets and Branches being, Behring Sea, or the Sea of Kamtschatka, the Gulf of California, and Bay of Panama; while of those on its western side the chief are, the Sea of Okhotsk, Sea of Japan, Yellow Sea, China Sea, and Gulf of Siam, with the Gulf of Carpentaria in Australia. This ocean is especially characterised by the immense number of Archipelagos—many of which are of volcanic, and others of submarine coral formation—that are scattered over its surface, especially in its western and central parts. North of the Tropic of Cancer the principal groups are, the Japan Isles, Kurile Isles, Aleutian Isles, Queen Charlotte's Island, and Vancouver Island. South of the Tropic of Cancer, and proceeding from W. to E., we find Malaysia, or the Malay Archipelago, the Ladrones, Caroline Isles, Marshall Archipelago, Sandwich

Isles, and the Galapagos Islands near the South American coast. Then returning westward, we come to the Marquesas, Low Archipelago, Society Islands, Hervey or Cook's Islands, Navigators' Islands, Friendly Islands, Fiji Islands, Queen Charlotte's Islands, Salomon Isles, New Hebrides, New Caledonia, and New Zealand. Its chief **Afluents** from the Old World are, the Amour, Hoang-Ho, Yangtse, Cambodia, Meinam; and from the New World, the Fraser, Columbia, and Colorado. The principal **Current** of this ocean is called the Equatorial current, which, originating in the Antarctic Drift current, flows N. along the western shores of South America (where it is called Humboldt's current), to the coast of Peru, and then W. through the Pacific in two branches, one north of the equator, and the other south of it, with a warm current, known as the "counter-equatorial," flowing between them, in the opposite direction. It travels at the rate of two or three miles per hour, and occupies the entire space between the tropics, producing a genial coolness, where otherwise the heat would be almost insupportable. Opposite Lima, on the Peruvian coast, its temperature is 14° below that of the neighbouring ocean; and even at Payta, which is 7° degrees further N., it is 10° degrees colder than the sea in its vicinity. The northern branch advances unbroken to the Philippine Islands, where it divides, the principal part turning N. and forming the warm, powerful Japanese or Kuro Sivo current, which is perfectly analogous to the Gulf Stream of the Atlantic; south of the Aleutian Isles, it is deflected eastward to the North American coast, and re-enters the Equatorial current. The southern branch of the Equatorial current turns southward and forms the New Zealand and Australian currents, which ultimately unite, and finally reunite with the Antarctic Drift current.

The Indian Ocean separates Malaysia, Australia, and Tasmania, on the east, from Arabia and Africa on the west; its northern boundary is formed by the shores of India and Biluchistan, and its southern, by the Antarctic Circle. Its shape would have approximated to an equilateral triangle, had not Asia projected its hugest peninsula into its apex, and given it a very irregular form. Extending from a little beyond the Tropic of Cancer to the Antarctic Circle, its greatest length is 90° , or about 6000 miles; while its extreme breadth, from Cape Agulhas to Tasmania, is expressed by the same number. The area is generally estimated at 25,000,000 square miles, or 20,000,000 when its southern boundary is formed by a line connecting South Cape, in Tasmania, with Cape Agulhas in Africa. The greatest **depth** hitherto discovered is E. of Ceylon, where in lon. 85° it is 2340 fathoms, but occasional soundings in the south-western part indicate depths equal to the maximum of the Atlantic.

In proportion to its magnitude it equals even the Atlantic, as to the number and extent of the **Branches** which it sends into the land, especially on its northern frontier. The principal of these are the Bay of Bengal, the Arabian Sea—with its members, the Gulf of Kachh, Gulf of Oman, and the Persian Gulf—the Gulf of Aden with the Red Sea, the Channel of Mozambique, Encounter Bay, St

Vincent Gulf, Spencer Gulf, and the Great Australian Bight, in Australia. The only **Islands** of considerable magnitude are Madagascar and Ceylon; but smaller islands and archipelagos are numerous, as Bourbon, Mauritius, Comoro, Amirantes, Seychelles, Socotra; the Laccadive, Maldivé, and Chagos archipelagos; Rodrigues; the Andaman, Nicobar, and Mergui archipelagos; Keeling Islands; St Paul and Amsterdā; Kerguelen or Desolation Island, &c. Its larger **Amuents** are nearly all from the Asiatic continent, as the Irawadi, Brahmaputra, Ganges, Mahanadi, Godaveri, Krishna, Tapti, Nerbudda, Indus, and Euphrates; together with the Zambezé from Africa, and the Murray from Australia. The Equatorial **current** of this ocean flows westward from the Indian Archipelago and Australia, to the east coast of Africa. On reaching Madagascar, it is divided by that island into two branches, one of which, called the Mozambique current, flows southward between Madagascar and the mainland, while the other flows in a more direct course on the east side of the island; then having united to form the Agulhas current, it pursues a south-westerly direction, till it arrives off the Cape of Good Hope, where a small part shoots northward into the Atlantic, but the main stream is deflected eastward by the Agulhas Bank (here 200 miles broad) and by the Antarctic Drift current, when, forming the Retrograde current of the Indian Ocean, it travels at the rate of 50 miles a-day, and is of immense importance to ships bound for Australia.

The **Arctic Ocean**, or north polar basin, is bounded in general by the northern shores of Europe, Asia, and America, all of which remarkably conform to the parallel of 72° , and hence its form is nearly circular, and its usual breadth 2500 miles. In other directions it is bounded by the Arctic Circle, which separates it from the Atlantic and Pacific Oceans, and forms the northern limit of sunshine in winter. Its greatest length from Behring Strait to that point on the Norwegian coast at which the Arctic Circle cuts the land—that is, along the meridian of 124° E.—is 3240 miles; and the total area is estimated at 5,000,000 square miles. Except on the Atlantic side, the waters of this ocean are virtually land-locked, the outlet by Behring Strait being only 36 miles wide, with a maximum depth of 25 fathoms. Numerous attempts have been made to reach the Pole, but as yet all have proved unsuccessful. The latest was by the British Expedition under Captain Nares, which returned to England in October 1876. Captain Nares, proceeding up Davis Strait and Smith Sound, penetrated as far as $83^{\circ} 20'$, being 20 miles beyond the furthest point hitherto attained, and only 400 miles from the Pole. Instead of finding an open sea, his progress was checked by a huge barrier of ice of between 80 and 120 ft. in thickness. The **depth** of water here was 72 fathoms, and the lowest winter **temperature** 72° below zero. The summer is very short, but warm and genial. Vegetable and animal life exists sparingly as far north as lat. 83° , where it seems to terminate. In lat. 82° a few musk-oxen, hares, and ptarmigans were found (see above, "Day and Night," p. 30). The long-sought *North-West Passage*—that is to say, a navigable

passage from European countries to China, along the northern coast of America—was at last, after innumerable unsuccessful efforts continued for two centuries, effected by Captain Maclure, who, in 1856, achieved the hazardous task by sailing out of the Pacific through Behring Strait; then, turning eastward, pursued his course along the coast till he came to Cape Bathurst, at the entrance to Coronation Gulf; then northward, along the west coast of Banks Land to Melville Sound, which he entered; and continuing his dangerous voyage eastward to Baffin Bay and Davis Strait, he finally entered the Atlantic. It now appears, however, that the honour of the discovery is really due to Sir John Franklin, who left England in search of a north-west passage in 1845, but who perished with all his crew in 1847. Notwithstanding the success of this brilliant exploit, the route thus discovered is all but absolutely impracticable, and can never be of any avail in a commercial point of view.

The principal **Branches** of the Arctic Ocean are, the White Sea, in Europe; the Gulfs of Kara, Obi, and Yenisei, in Asia; Behring Strait, between Asia and the New World; and Coronation Gulf, Melville Sound, Barrow Strait, Lancaster Sound, and Baffin Bay, in North America. The **Rivers** that find their way into this ocean are, for the most part, of great magnitude. Having their sources as far south as the 50th parallel in both hemispheres, they drain an area fully equal to that of the ocean which they enter, or considerably more than that of the continent of Europe. The chief of those from the Old World are the Dwina, Petchora, Obi, Yenisei, Lena, and Kolyma; and from the New World, the Colville, Mackenzie, and Coppermine. The northward direction of these rivers imparts a striking peculiarity to the annual thawing of their waters. As their upper courses belong to more temperate latitudes than their lower, the former are melted by the heat of the sun at an earlier date than the latter, and discharge their liberated contents into the valleys and estuaries below, which, being thus inundated by waters of a comparatively elevated temperature, speedily give way in turn; and thus, in a comparatively brief period, the entire ocean is covered with an immense volume of fresh water of more than 32° of temperature, which now becomes the prime mover of that **ocean current** that, every summer, drifts the polar ice into the Atlantic. Another cause, however, co-operates in producing this phenomenon. The north-east branch of the Gulf Stream from the Atlantic enters the Arctic Ocean between Norway on the one side, and Iceland and Spitzbergen on the other. Doubling the North Cape, it flows eastward, close to the shores of Lapland and Siberia, the rigorous climate of which it materially softens. Arriving at Behring Strait, it is greatly increased in volume and force by the Japan current from the Pacific, and now pursuing its circuitous journey, it eventually arrives at Banks Land and the Parry Islands. The **Islands** of this ocean are but imperfectly known. They are for the most part uninhabited, and are important only as the temporary abodes of the whale, seal, and walrus hunter. The principal groups are the following: Spitzbergen, Novaia Zemlia, Franz Joseph Land, and New Siberia, between the Pole and the

eastern continent; and the great North American Archipelago (the chief members of which are the Parry Islands, Banks Land, North Somerset, Cockburn Island, Cumberland Island, Cornwallis Island, North Devon, Ellesmere, Grinnell Land, Grant's Land) and Greenland, which is now known to be an island, its N.W. corner being in lat. $82^{\circ} 54'$, lon. $48^{\circ} 33' W$.

The **Antarctic Ocean** is far less accurately known to geographers than any of the other great oceanic basins, the cold being more intense, the winds and seas more boisterous, and the ice extending at least 10° nearer the equator than in the Arctic basin. The highest latitude yet attained in this ocean was reached by Sir James Ross, who, in 1841, penetrated to lat. $78^{\circ} 15'$, or within 705 nautical miles of the South Pole. In this latitude, and from the southernmost accessible point of Victoria Land, "an unbroken vertical cliff of ice, of about 1000 ft. in thickness, and floating in 280 fathoms of water, extends eastward for 450 miles." Other navigators, in approaching the Pole from other directions, have encountered similar obstructions at considerably lower latitudes, as Adelie Land, S. of Australia; Enderby Land, S. of Madagascar; and South Shetland, S. of Cape Horn. Probably, therefore, almost the entire area embraced by the Antarctic Circle is occupied by a continent which is nearly circular in form, and more than twice the size of Australia; which is covered by eternal snows, and wholly devoid of vegetation; the shores of which are guarded by gigantic volcanoes, or by impenetrable barriers of ice; and whose interior has never been trodden by the foot of man. One of these volcanoes, named Mount Erebus, was found by Sir James Ross to be 12,400 feet above the level of the sea, and in a state of constant activity; while Mount Terror, an extinct volcano, has an altitude of 9000 feet. **Depth.**—The Antarctic Ocean is much shallower than either the Pacific or Atlantic, though considerably deeper than the Arctic. The greatest depth obtained by the Challenger, in February 1874, south of Termination Land and within the Antarctic Circle, was 1975 fathoms, or 11,850 ft., being the deepest sounding she had made since leaving the Cape of Good Hope. Capt. Nares found at lat. $64^{\circ} S$. the mean temperature of the air in February to be $31^{\circ} 5'$ —a colder climate than is found in August in the Arctic seas, even at lat. $74^{\circ} N$. The Challenger entered the pack-ice in lat. $65^{\circ} 30' S$. At lon. $70^{\circ} 49' E$. the surface-water was always about 28.5 Fahr. (just warm enough to melt salt-water ice very slowly), while, at a short distance from the pack, it was found to be 32° . At the depth of 40 fathoms it was 29° , at which it remained constant to about 300 fathoms; below this the temperature rose to 33° or 34° . Unfortunately the bottom temperature was not ascertained, but Dr Carpenter believes it must be about 29° . Numerous voyagers testify that S. of the 50th parallel icebergs, scattered more or less, may be constantly fallen in with during the southern summer. Unlike those of the Arctic seas, which present so many fantastic shapes, these icebergs are very tame, nearly all presenting the same table-topped appearance, and divested of all coloured ornaments. In this ocean originate several of the grand ocean currents which so powerfully

modify the temperature of the continents. One such stream of intensely cold water, bearing the name of the Antarctic Drift current, proceeds northwards along the shores of Chili and Peru, then westwards through the Pacific and Indian Oceans under the name of the Equatorial current, and finally enters the Atlantic as the Agulhas current. The barometric pressure in this ocean is abnormally low throughout the year, with perhaps a slight tendency to an increase in July. Sir James Ross determined the position of the South Magnetic Pole to be within the limits of South Victoria Land—viz., in lat. $75^{\circ} 5' S.$, and lon. $145^{\circ} 8' E.$

Inland Seas.—Each of the oceans has its own system of inland seas, or projections of its members into the different continents. The principal of these are enumerated above under the respective oceans to which they belong. The Atlantic is especially characterised by its inland seas, or by seas lying within the general figure of the continents that confine its waters. Two of these, the Mediterranean and the Gulf of Mexico, are situated in warm regions; while other two, the Baltic and Hudson Seas, are in colder latitudes. Of other inland seas, the most interesting to us are the Red Sea, a branch of the Indian Ocean, and the Caspian, which is in reality a salt-water lake.

The Baltic, situated between Sweden and Russia, area 160,000 sq. m., depth nowhere exceeding 1100 ft.; hence, were the north of Europe to rise about 1000 ft., the Baltic would disappear. Its basin, which embraces one-fifth of the continent, is characterised by a greater snowfall than any other inhabited region. The amount of fresh water received by rain and rivers is very great, as compared with its loss by evaporation. The Baltic, accordingly, is greatly fresher than the ocean; the Gulf of Bothnia contains only .004 per cent of salt; but in the Baltic proper, the degree of salinity, near the bottom, is much greater. A surface current of brackish water flows outwards through the Sound, while an under current of saltier and therefore heavier water from the Atlantic flows inwards. Average temperature of surface 45° in the S., but in the N. about 35° . The tides are inappreciable.

Mediterranean.—A large inland sea between Europe and Africa; area, without including the Black Sea, 970,000 sq. m.; average depth 1200 fathoms, but 2000 fathoms in the E., and in the Str. of Gibraltar the maximum depth exceeds 500 fathoms. Average temperature 60° to 70° , but S. of Europa Pt., about 71° . Tides very slight. Receives an immense drainage from S. Europe, and from Africa by the Nile; still its waters are saltier than those of the Atlantic, being .029 per cent, while the Atlantic is .027. The amount of evaporation therefore must exceed the supply got from the rivers; indeed it is estimated that three times as much water as it receives from rivers is evaporated from its surface. Accordingly it is found that an immense surface current is constantly flowing inward from the Atlantic, while there is an under current flowing outwards. Owing to these two currents, the degree of salinity of the waters of the Mediterranean remains nearly constant.

Black Sea.—Area, including Sea of Azov, 180,000 sq. miles; lies bet. the isotherms of 50° and 60°; salinity (which varies from 1.012 to 1.014) is only half that of the Mediterranean, and is least in spring when the rivers are largest. As the rain and river supply is in excess of the evaporation, there is a strong surface outward current through the Bosphorus and Dardanelles. Depth of former about 50 fathoms.

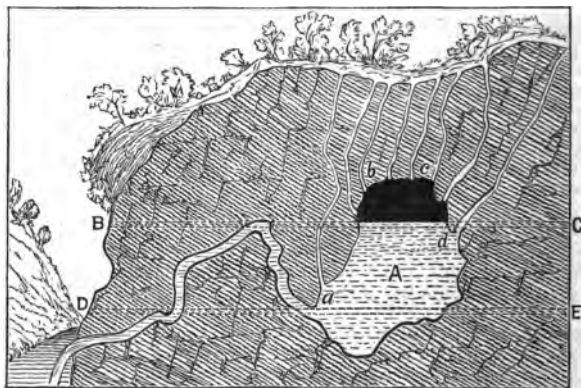
Caspian.—The Caspian is the greatest salt-water lake in the world, and is doubtless a survival of that great central sea which at no remote geological period covered a large part of Northern Asia, the gradual upheaval of land having separated it from the Black Sea, Sea of Aral, and Arctic Ocean. Present area, 180,000 sq. miles; surface, 83 ft. below the level of the Black Sea. Depth varies from 50 ft. in the north, to from 2000 to 3000 ft. in the south. Mean annual temperature from 50° to 60° Fahr. Receives the Volga, the largest European river, besides five other considerable streams. These exactly counterbalance the evaporation. Salinity very low, not exceeding $\frac{1}{4}$ that of the ocean.

Red Sea.—Area, 180,000 sq. miles; length, 1490 m.; greatest breadth, 200 m.; average depth about 220 fathoms. Since the construction of the Suez Canal, connecting it with the Mediterranean, the Red Sea has become of immense importance to all civilised nations, as it forms the great highway of commerce from Europe to the East. Though its northern end is in the temperate, it penetrates far into the torrid zone, besides communicating with the hottest ocean on earth. The surface temperature varies from 96° to 106° Fahr. The temperature of the air is frequently intolerable—the blackened bulb of a thermometer, laid on a black board, sometimes rising to 215°, and hence, though it receives no rivers, the amount of evaporation is prodigious. A surface current flows in through the Str. of Bab-el-Mandeb at the rate of 30 m. a-day, while an under current probably flows outward towards the Indian Ocean, without which the bed of the sea would, in the course of time, become filled with salt. Its salinity is estimated at .039, or 50 per cent higher than the Atlantic, hence it is the saltiest known sea in communication with the ocean.

Waters of the Land.—Having thus surveyed the grand reservoirs of waters called oceans, we must now glance at the waters of the land, and this we shall best accomplish by considering springs, rivers, and lakes.

Springs.—On a subsequent page we shall show that when more aqueous vapour enters the atmosphere than it can retain, a portion is condensed and falls to the surface in the form of rain. This rain ultimately finds its way to the ocean, or back to the atmosphere by evaporation. This can be put to the test by carefully observing what becomes of the water when a heavy shower of rain falls. The first portion is spent in wetting the ground, and at the end of the shower this portion evaporates. The major part, however, flows off in gutters, ditches, and brooks close by; multitudes of these converge into rivulets, and find their way to larger streams and rivers which have their natural outlet in the sea. But a very considerable portion of the water still remains to be accounted for. By digging down a few inches we observe that the rain has penetrated the soil to some distance from the surface, the depth depending on the dura-

tion of the shower, its copiousness, and the more or less compact nature of the soil. This portion irrigates the ground, moistens the roots of plants, and by the carbonic acid which it carries with it out of the atmosphere, acts chemically on the soil, and fertilises it. Should the rain continue to fall heavily and continuously for days, and should the soil be porous, the rain will make its way to a considerable depth, and probably extend to the permanently wet subsoil. By excavating deeper, we shall discover that any further moisture penetrating the soil either sinks through the rock, if of a sandy or porous nature (like sandstone or chalk), or, encountering a harder rock or bed of clay, it will ooze along in a more or less horizontal direction until it finds a crack or fissure by means of which it can arrive at a subterranean cavern, or some other lower level, and ultimately reappear at the surface, in a valley or on the sea-shore, in the form of a well or SPRING, which may be situated miles away from the place at which the rain descended. Should the scene of our experiment belong to a region characterised by a tolerably constant rainfall, the spring will be permanent throughout the year; but if the rainfall is periodic, the spring will in like manner be periodic or intermittent.



Intermittent Spring.

The true character of an Intermittent Spring will be evident from the accompanying diagram. A is an interior cavern into which small tributary channels, *a b c d*, empty themselves, and which is drained into the valley by a siphon-like passage. The water accumulates in the cavern till it attains the level B C, for there only does it rise to the highest point of the siphon. Having begun to flow, the discharge will continue until the water sinks to D E, the mouth of the siphon, below which it cannot fall, as now the air gets into the siphon. The spring will then cease to flow until the water reascends to B C.

Rivers are of vast importance in nature. What drains and gutters are to the roads and streets, and ditches to the low-lying fields, rivers are to the country at large. They collect the surplus rainfall not required by the soil, and transport it again to the ocean, which is the great reservoir or tank into which all the waters discharge themselves (see "Springs," p. 65). Rivers are majestic trees that have their roots fixed in the ocean, and their tops reaching the clouds; the great cities of the world hang around their stems; while the towns and villages cluster like fruit on their branches. Till very recently, when the canal and railroad have to some extent supplied their place, rivers have in all ages formed the great **highways of commerce**. In every land their banks present the most fertile portions of the country, as the valleys of the Tigris, Euphrates, and Nile; and have formed the earliest seats of civilisation—as, for example, Nineveh, Babylon, Heliopolis—the origin of which dates back to the dawn of history. Rivers are fed by snow, rain, glaciers, and especially by springs, which are the outflow of rain that has previously sunk into the ground through porous strata. From a variety of causes, springs are most numerous and copious in mountain regions; accordingly rivers find their sources on plateaux and mountains. A **river-basin** is the whole tract of country drained by a river and its tributaries, while the basin of a lake or ocean includes all the rivers with their affluents which discharge themselves into it. The elevated ridge which separates one river-basin from another is now denominated by most geographers the **water-parting**; while the sides of the hills sloping down from this ridge towards a river, and from which it receives the drainage, is usually named the **watershed**. The **size and volume** of a river depend on the rainfall of the basin, which in turn is affected by the quantity of wood in the valley, and the amount of water absorbed by the vegetation on its banks (see p. 83). The volume varies with the seasons, and all rivers are annually liable to floods. In tropical countries these are periodical and regular, owing to the rains which fall in the mountains where they rise; while in temperate regions, on account of the variability of the seasons, and the melting of the snow in the mountains, they are accidental and sudden, and consequently very destructive.

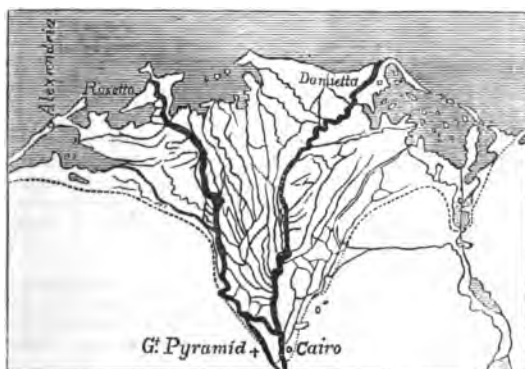
The **velocity** of a river is in proportion to the inclination of its bed, and is greater at the centre and surface than at the bottom and sides. The average slope of the bed is 6 inches in the mile, or about 1 in 880; if the slope be 1 in 200, the stream is not navigable. The fall, however, is not uniform throughout the whole length of the course, being greatest in the upper part, and gradually diminishing, until near the mouth it is almost nothing.

Action of Rivers.—Rivers are powerful agents in the work of erosion, reconstruction, and levelling that is constantly taking place on the surface of the earth. As has been already explained, the mists and rains on the summits of mountains are the main source of running water. The drops make the rill, the rills form rivulets, and these again unite into torrents which, working with increasing force, excavate deep gorges on the mountain-sides. The torrent has its

greatest force at the bottom of the steep declivity, and there the valley first takes shape and size, the excavation being often very deep, though narrow, with sloping and occasionally precipitous sides. In the *middle and lower course* the stream erodes more at the sides than at the bottom, constantly widening the valley, especially during freshets, when the velocity and eroding action of the water becomes immense: indeed two or three centuries of erosion will form gorges in the solid rock hundreds of feet in depth. The windings of a river, in large alluvial flats, are greatest where the current is slowest, as slight obstacles change its course; its length between two given points being twice or thrice the distance in a direct line. The length of the Mississippi, between the mouth of the Ohio and the Gulf of Mexico, is 1080 miles, the direct distance being only 500 miles. Rivers of great volume and power are less easily deflected from their once established course, hence their windings are much larger. The amount of transportation carried on by rivers is beyond calculation—every stream, great and small, being engaged in carrying sediment derived from the corrosion of the land surface. It is estimated that about $\frac{1}{1000}$ part of a vertical foot of the basin is the average amount of material transported annually by a river. In many instances, however, the quantity is far greater than this: for example, the Mississippi contributes annually to the Gulf of Mexico *detritus* sufficient to cover 1 sq. mile to the depth of 268 ft.; while the material borne down by the Ganges to the Bay of Bengal would cover a sq. mile to a depth of 228 ft. The materials transported consist of stones, sand, and fine earthy matter termed silt, together with large quantities of trees and timber, and sometimes the carcasses of animals drowned by freshets. The larger rocks and stones are generally left in the upper course of the river, but the smaller are carried down, and gradually disappear, being reduced by friction and partial decomposition to the fine sand we find on the shore of the ocean into which the river discharges itself.

Deltas.—The transported sediment forms about the river's mouth more or less extensive flat plains which, when intersected and surrounded by water-channels, are termed *deltas*, from their resemblance to the Greek letter Δ (delta). Deltas occupy low level portions of the coast, and occur both in the open ocean and in inland seas. In the former, as in the mouths of the Ganges, Orinoco, and Niger, the ebb and flow of the tide are always observed, but in the latter there is little or no tidal movement, as in the deltas of the Volga, Po, Ebro, and Mississippi. The formation of deltas in open oceans is favoured by the winds blowing against the current of the rivers. Again, in inland seas, a bar at the estuary of a river favours the deposit of sediment behind it, and contributes to the encroachment of the land upon the sea, of which the valley of the Euphrates, Holland, and Lower Egypt (styled by Herodotus "the creature of the Nile") are good examples. This addition to the horizontal area of the land is, however, very small in comparison to the vertical waste effected by the agency of rivers. The head of a delta where it bifurcates is the original mouth, as in the case of the Nile, which in

ancient times entered the sea in the vicinity of the Pyramids of Gizeh.



Nile Delta.

Waterfalls.—The inequalities in a river's bed occasionally assume the form of deep precipices, down which the water bounds in imposing **Cataracts**. The highest of these occur in the *upper* courses of rivers, as the celebrated Yosemite Falls, on the Merced, in California, the loftiest in the world—being half a mile high, or sixteen times higher than Niagara. The greatest falls, however, for volume of water, occur in the river's *middle* course, as the Victoria Falls, on the Zambezi, and the Falls of Niagara on the St Lawrence, the most magnificent in the world, being estimated to discharge 100 million tons of water per hour. When the current flows over *smaller* inequalities in the bed, **Rapids** are formed, which greatly interfere with, if they do not entirely obstruct, the navigation of a river.

The Principal Rivers of the Globe having been already enumerated under the different oceans, in the following table we give only a few of the larger rivers in each continent, with the Thames as a standard of comparison, together with the length of the course and area of basin:—

Name of river.	Total length in Eng. m.	Area of basin in sq. miles.	Name of river.	Total length in Eng. m.	Area of basin in sq. miles.
Europe—			Asia—		
Thames	250	600	Euphrates	850	195,680
Elbe	550	55,000	Indus	950	312,000
Rhine	600	75,000	Ganges	1000	432,000
Loire	530	44,500	Brahmaputra	700	330,000
Rhone	645	37,900	Yang-tse	1800	547,800
Danube	1795	306,000	Amoor	1250	582,880
Volga	2400	527,000	Yenisei	1950	784,530

TABLE—*continued.*

Name of river.	Total length in Eng. m.	Area of basin in sq. miles.	Name of river.	Total length in Eng. m.	Area of basin in sq. miles.
Africa—			America—		
Nile	4000?	520,000?	St Lawrence	1400	297,600
Zambeze	1430	?	Mississippi	1820	982,400
Orange	1000	?	Rio del Norte	1050	180,000
Congo	?	?	Mackenzie	1200	441,600
Niger	2000	?	Orinoco	1000	252,000
Senegal	1000	?	Amazon	2100	1,512,000
Gambia	1000	?	Parana	1600	886,400

Lakes are large inland sheets of water which occupy natural depressions of the earth's surface. As drainage agents they play an important part in nature, as they are the tanks or reservoirs for storing up and distributing gradually the surplus waters. Lakes are divided into five classes:—

1. *Lakes of transmission*, or those which both receive and discharge rivers, of which they are but expansions. Such lakes are always fresh, and form the most numerous and important class. The great African and North American lakes are good examples.

2. *Lakes of emission*, or those which discharge, but do not receive streams. They are fresh and small, and are fed by rain or by springs bursting up in their beds. Such lakes frequently form the sources of mighty rivers, as Seligher, in the Valdai Hills, from which the Volga issues.

3. *Lakes of reception*, or those which have feeders, but no visible outlets. They are generally large, and either salt or brackish, as the Caspian, Sea of Aral, Dead Sea,* Gt. Salt Lake, and Lake Balkash, most of which are beneath the level of the ocean, and are continually becoming saltier, as their waters are mainly lost by evaporation, and of course the water only evaporates.†

4. *Lakes which neither receive affluents nor have any visible outlet.*—They generally occupy craters of extinct volcanoes, and are very small, as Averno and several others in Italy.

5. *Periodic lakes*, which do not essentially differ from intermittent fountains, as Zirknitz See, in Illyria, whose waters disappear every June through subterranean passages. In winter it abounds with fish, but in summer its bed is dry and regularly cultivated.

Lakes are very numerous in highland regions, where they form deep reservoirs in the bosom of the mountains. Such lakes are never

* The Dead Sea is the lowest, and next to Tüz-Göl, in Asia Minor, the saltiest body of water known. No living creature exists in its waters, as they are now a heavy brine, and so buoyant that men bathing in them find themselves floated like cork.

† It now appears, notwithstanding Cameron's discovery of the Lukuga, that the large fresh-water lake Tanganyika has no outlet (see H. M. Stanley's letter, dated Ujiji, August 7, 1876).

of great size, but are long and narrow, and frequently celebrated for the grandeur and beauty of their scenery, as those of Scotland, Cumberland, Italy, and Switzerland; lakes of lowland regions, on the other hand, are tame, but are often of great extent, and broad and shallow in proportion to their area. Such are the enormous lakes of Africa and N. America, and those of Sweden and Russia. The Caspian (area 178,866 sq. miles, and 83 feet below the level of the sea) is the largest lake in the world; Lake Superior (area 32,000 sq. m.) the greatest fresh-water one in the New World; and the Victoria Nyanza (nearly its equal in size) the largest in the Old; Tûz-Gûl, in Asia Minor, is the saltiest known lake; the Dead Sea (1312 ft. below the ocean-level) the lowest; and the Sir-i-Kol (15,600 ft. above the ocean-level) the most elevated. North America is pre-eminently the continent of lakes—the combined area of the five great Laurentian ones amounting to 91,300 sq. m., or more than the area of Britain with its adjacent islands.

Islands.—Islands are sometimes roughly defined as land surrounded by water, but they are rather the tops of mountains appearing above the sea-level. Though almost countless in number, they are believed to form in their aggregate only $\frac{1}{4}$ part of the land surface of the globe. By far the greater number are of very small dimensions, while the seven largest are Greenland, Borneo, Papua, Madagascar, Sumatra, Nippon, Great Britain, the largest of which is $\frac{1}{16}$ the size of Europe. Islands greatly differ, not only in size, but in position, structure, flora, fauna, and many other characteristics—a careful study of which leads to striking results. They may be divided into two classes—continental and oceanic—the latter being subdivided into volcanic and coralline.

Continental Islands are those which are situated near continents: of the latter they no doubt once formed an integral part, the separation having arisen from a slight depression of the continental margin. Not only are the dividing seas exceedingly shallow, but the geological structure of these islands is identical with the mountain-chains of the mainland, and both are characterised by the same varieties of plants and animals. Were the bed of the North Sea, for example, elevated 300 feet above its present level, Great Britain would again form part of the mainland of Europe. In Southern Europe, in like manner, we find the Balearic Islands connected with Spain, and Corsica and Sardinia with Northern Italy. Again, Iceland, and even Greenland, appear to have been at one time united to Northern Europe. The intervening ocean is shallow, while the plants and animals are North European, and not North American. The Japanese group of islands are, strictly speaking, a part of Asia, as they conform in direction to the mountain-chains of the mainland. The western islands of the Indian Archipelago, Borneo, Sumatra, Java, &c., are similarly united to that continent, the depth of the intervening seas seldom exceeding 300 ft., while all the eastern mem-

bers of the Archipelago, Papua, Celebes, &c., formed part of the Australian continent, from which they are now separated by only 180 ft. of water. The former possess an Asiatic fauna, while the latter contain the same marsupial group of animals that characterise Australia. Similarly, New Zealand and Norfolk Island belonged to Australia, as is evident from the fact that the bones of the strange bird, the *Dinornis*, once common in New Zealand, are found in Queensland. Again, Newfoundland was united to Nova Scotia; Cuba and Hayti to Yucatan; Trinidad to Venezuela; Falkland Isles and Chiloe to Patagonia; and Vancouver Island to British Columbia. Africa is connected with no continental island with the exception of Sicily, which was at one time joined to Tunisia, for Madagascar appears never to have been attached to it, the intervening channel being very deep, and the fauna and flora being quite dissimilar. For example, the lemurs of Madagascar are quite unlike the African apes, while the now extinct *Apyornis* has nowhere been found on that continent (see "Extinct Species of Animals").

Oceanic Islands are the summits of upheaved mountains. They occur in groups and bands, and are more numerous in the Pacific than in any other ocean (see p. 25). Omitting New Caledonia and some other of the larger islands in the S.W., for the most part they stretch out, in a S.E. direction, in a line 8000 m. long, from the neighbourhood of Japan to Easter Island, lat. 27° S., lon. 110° W.—the most easterly of all the countless islands of this ocean. In contrast to continental islands, these are characterised by an absence of indigenous animals and plants—the former having been invariably carried to them either by human agency or by ice, while the latter are always closely allied to those of the mainland from which the prevailing winds and currents arrive (see under "Modes of Dissemination of Plants and Animals," and "Volcanic and Coral Islands").

V.—THE ATMOSPHERE.

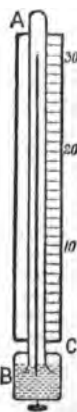
Many of the phenomena of physical geography are inexplicable without some previous acquaintance with that thin, aerial, and invisible fluid called the Atmosphere, which envelops the earth on all sides, which shares in its diurnal motion, and which accompanies it in its annual journey round the sun.

Composition.—In respect to composition, atmospheric air consists almost exclusively of two gaseous, elementary substances, oxygen and nitrogen, in the proportion of 21 parts by volume of the former, and 79 parts of the latter, or, 23 parts by weight of oxygen, and 77 of nitrogen. It also contains a little carbonic acid gas, a minute though very variable quantity of aqueous vapour, and a trace of ammonia. The oxygen and nitrogen are not chemically combined, but exist in a state of mixture; yet their relative proportions remain invariable,

being the same on the summits of the highest mountains as in the deepest recesses of the surface, the same in the country as in the crowded city, and the same in the tropical as in the frigid zones (see p. 28). On the contrary, the carbonic acid and vapour of water vary greatly in quantity in different localities, the one being affected by local causes, and the other mainly by changes of temperature.

Density and Pressure of the Atmosphere.—Notwithstanding its extreme lightness, the air, in common with all other material bodies, is affected by the all-pervading law of gravitation, and exerts a pressure on the surface of the earth which can easily be measured. According to Dr Prout, 100 cubic inches of pure dry air, at 60° of temperature, and the barometer standing at 30 inches, weigh 81 grains. Now, as 100 cubic inches of distilled water at the same temperature weigh 25,252 grains, it follows that air is 813.67 times lighter than water, and 10,500 times lighter than mercury. The weight on every square inch of surface at the level of the sea generally amounts to about 15 lb. avoirdupois (14.7 lb.), being the same as the weight of a column of water of equal base, 34 feet high, or of a column of mercury 30 inches high. The entire weight of the atmosphere is, therefore, upwards of 5000 trillion tons. Supposing the surface of a man's body to measure 15 square feet, it sustains a pressure of no less than fourteen tons. Being a highly elastic fluid, the density and pressure of the atmosphere rapidly diminish as we ascend upward, 1000 feet of ascent (near the surface) roughly corresponding to a fall of one inch in the barometer; or, to speak more exactly, *As the elevation increases in arithmetical progression, the density and pressure decrease in geometrical progression.* Thus, at the level of the sea, the pressure on each square inch is 15 lb., or equal to a column of mercury 30 inches high; at 3.4 miles above the surface the pressure is only 7½ lb., or 15 inches of mercury; and at 6.8 miles of elevation, 3¾ lb., or 7½ inches of mercury. From this the application of the **barometer** (*baros*, weight; *metron*, measure) in ascertaining the heights of mountains becomes obvious.

This instrument is a slender glass tube about a yard in length, closed at one end, then filled with mercury and inverted, the open end being then placed in a cup, B, of the same fluid. The atmosphere, pressing upon the fluid in the cup, sustains within the tube a column of mercury exactly sufficient to balance its own weight. At the level of the sea, this column, measured by a scale A C attached to the instrument, is about 29 or 30 inches in height. If, now, we carry the instrument with us to the summit of a mountain, the height of which we wish to ascertain, and find the mercury in the tube only 15 inches high, then we know that the mountain is 3.4 miles, or 17,952 ft. in height—the height of Mount Demavend. Another way of determining the height of a mountain is by the *thermometer*—viz., by observing the



Barometer.

degree of temperature at which water boils at the summit. At the level of the sea, pure water boils at 212° Fahr., but at Quito, in South America, which is known to be at an elevation of 9643 ft., water boils at 194° , or 18° lower. From this we obtain the convenient rule that the boiling-point of pure water is lowered 1° Fahr. for every 530 feet of ascent. The barometer is also of incalculable value to the mariner when sailing over the wide ocean, where he encounters climates altogether new to him. If there is observed a great and sudden fall in the mercury, the vigilant captain knows that a tempest is close at hand, and hence he instantly furls the sails, and avoids the fate which would otherwise be inevitable. To the husbandman it is also of signal service in foretelling sudden changes of weather. By long and careful watching, he can form a reliable estimate in the morning whether the day is to be calm or windy, fair or rainy.

Height of the Atmosphere.—Many reasons combine to induce the belief that the atmosphere does not extend to an indefinite height. Until lately it was supposed that it terminates at an altitude of from 45 to 50 miles, but from recent researches on luminous meteors, which become visible only when they penetrate the atmosphere, the absolute height cannot be less than 120 miles, and it may extend even to 200 miles, or $\frac{1}{4}$ of the earth's radius. Mr Glaisher, the celebrated English aeronaut, succeeded, in 1863, in ascending in a balloon to a height of 36,670 ft., or nearly 7 Eng. miles. Its height is different in different latitudes, being considerably greater between the tropics than within the polar circles. This is owing partly to the greater centrifugal force that exists in the equatorial than in the polar regions (caused by the rotation of the earth on its axis), and partly to the high temperature of the earth's surface in low latitudes, which causes the air in contact with it to expand at the rate of $\frac{1}{417}$ of its volume at 32° Fahr. for every increase of 1° . Sir James Ross observed that, in South Victoria Land, lat. 78° , the barometric pressure rarely exceeded 29 inches, whereas in the torrid zone it averages about 30.

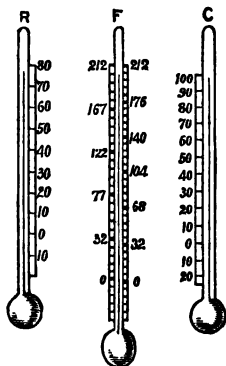
Temperature of the Atmosphere.—When ascending the side of a mountain-chain, the traveller feels the cold increasing perceptibly in proportion to his elevation; and should the chain be sufficiently lofty, he will find the summit covered with perennial snow. If the ascent is made within the tropics, the difference of temperature arising from elevation is beautifully represented to the eye by a corresponding succession of climatic zones, each of which is occupied by a fauna and flora peculiar to itself, but quite analogous to the succession of zones, with their respective faunas and floras, that is traversed when proceeding from the equator to either pole. This beautiful phenomenon, of which the Andes and Himalaya afford the most striking examples, depends on the fact that any change in the density of the atmosphere is uniformly accompanied by a corresponding change in its temperature. When a gaseous body expands, a portion of its heat becomes latent, and the amount of heat required to raise it to any given temperature increases the more the gas expands. If there be no source of heat from which this additional quantity can be obtained, the gas will cool during expansion, by a portion of its free

heat becoming latent. Generally speaking, the thermometer sinks 1° Fahr. for every 333 ft. of elevation for the first mile above the surface, but the rate is influenced by many causes, such as dryness, moisture, currents, &c. For higher elevations no regular law has been ascertained.

Thermometers.—Variations of temperature are measured by an instrument called the thermometer (*therme*, heat; *metron*, a measure), in which advantage is taken of the fact that heat expands all bodies. Solid bodies, however, expand too little to be of use in measuring ordinary changes of temperature, and gases too much: hence liquids are employed in thermometers. Of these, mercury is practically the best adapted for this purpose, as there is a considerable range of temperature between its freezing and boiling points: the former taking place at 40° below zero, and the latter at 662° above it. This is the only metal (except, possibly, caesium and gallium) found liquid at ordinary temperatures. For very low temperatures alcohol is used, as it does not freeze, but air is employed in very delicate experiments.

The instrument most commonly used in this country is named after Fahrenheit, a German who invented it in 1726. He took a long narrow glass tube with a bulb at the extremity, and nearly filled it with mercury; then heated the bulb, causing the mercury to expand till it began to overflow, then melted the glass at the top of the tube by means of a blowpipe, and hermetically sealed it. He next proceeded to graduate the instrument by plunging it into a mixture of pounded ice and salt, the greatest artificial cold then known. The point at which the surface of the mercury then stood he marked *zero*. He next placed the instrument in the steam of boiling water, and marked the point at which the mercury now stood. The space between these two fixed points he divided into 212 equal parts, and found that water freezes at 32° , and boils at 212° , being an interval of 180° . The great defect of this instrument is that it does not adopt the freezing-point of water as its zero, as is done by Reaumur's thermometer and the Centigrade. The former, which is used in Russia and Sweden, divides the interval between freezing and boiling water into 80 equal parts; and the latter (which is in common use on the Continent) into 100 parts. In comparing the three thermometers, we have only to observe that the same space is divided by Fahr. into 180° , by the Cent. into 100° , and by Reaumur into 80° ; the three numbers being as 9, 5, 4. Hence, to convert Fahr.'s scale into either of the others, care must be taken first to deduct the 32° which the other two have not in common with it. Thus, if we wish to find how 120° of Fahr. would be expressed on the C. scale, we proceed thus:—

$$120^{\circ} - 32^{\circ} = 88^{\circ}. \text{ Then } \frac{88 \times 5}{9} = 48\frac{4}{9}^{\circ} \text{ C.}$$



If, again, we wish to convert 100° C. into Fahr. scale, the operation will be the following:—

$$\frac{100 \times 9}{5} = \frac{900}{5} = 180^{\circ}. \text{ Then } 180 + 32 = 212^{\circ} \text{ Fahr.}$$

Motions of the Atmosphere: Winds.—When the air is put in motion by any cause, a wind is produced; and no causes so powerfully contribute to such motion as local changes of temperature and pressure, arising from the unequal degree in which portions of the earth's surface are heated by the solar rays. In order to obtain a clear notion of the nature and direction of winds, it will be necessary to leave out of view, for the time, the various inequalities of the earth's surface, and to regard it as uniformly spherical. In tropical regions, where the sun is always vertical at noon, his rays fall perpendicularly on the surface, and consequently with a far greater heating power than if they came down slantingly, as in the temperate and frigid zones. The heated surface communicates its own temperature to the stratum of air in contact with it, causing the latter to expand, and, with a diminished density, to ascend through a higher stratum, supported by which it flows off towards the nearest cold region, its place meanwhile being supplied by other currents proceeding along the surface from adjacent cold regions. Hence we should expect that at any point on the surface in the northern hemisphere, northern winds (that is, winds *from* the north) would prevail throughout the year; while everywhere in the southern hemisphere they would blow incessantly from the south. And, were the earth at rest, and its surface wholly land or water, such would be the actual direction of the winds throughout the year. But the earth rotates on its axis from west to east every twenty-four hours, its equatorial parts moving at the rate of 1000 miles per hour, while at the poles the surface remains at rest. Hence, in passing from the higher latitudes towards the equator, the cold currents of air arrive progressively at regions of increased rotatory velocity; and as they cannot keep pace with this increase of motion, they necessarily lag behind, and form currents flowing in a direction opposite to the rotation of the globe, or from *east* to *west*; and thus, by the combined effects of the rotation of the globe and the difference of temperature at its surface, the northern and southern currents are deflected and modified, so as to become respectively the permanent north-easterly and south-easterly currents, forming the magnificent phenomenon of the **Trade-winds**. These winds extend, with occasional interruptions and modifications, from the vicinity of the equator to the 28th or 30th parallel, N. and S.—the limit varying according to the sun's northern or southern declination. Their action is most regular in the Atlantic and Pacific Oceans; but their influence is neutralised in the vicinity of continents and large islands by the currents that are generated on the land. In the Indian Ocean and south-eastern Asia, the trade-winds undergo remarkable modifications, changing their direction at certain seasons of the year, and hence called **Monsoons** (Arabic *mausim*, a season).

These winds prevail over a tract extending from lat. 7° S. to the Tropic of Cancer, and from the E. coast of Africa to Japan, Siberia, and the W. Pacific Ocean. They blow for six months of the year in one direction, and for the other six in an opposite one. The change occurs about the 15th April and the 15th October, and is accompanied by sudden and violent gales and terrific thunderstorms. On the north side of the equator the N.E. monsoon prevails, with little variation, from October to April; while from April to October it is replaced by the S.W. monsoon. In the W. part of the Indian Ocean, south of the equator, the N.E. monsoon blows from October to April, constituting the rainy season; while from April to October the S.E. monsoon holds sway, and forms the dry season. The last-named monsoon may be considered as identical with the S.E. trade-wind. In general, the monsoons blow towards the Asiatic continent during summer, and in an opposite direction in winter. They regulate the alternations of the wet and dry seasons throughout south-eastern Asia—the rainy season of the W. coast of India corresponding with the prevalence of the S.W. monsoon, and that of the E. coast with the S.E. monsoon. They are also of great importance to commerce, for by them a ship may be wafted to a distant port, where she remains till the monsoon changes, and is then aided by it home again. Monsoons are caused by the unequal heating of the land-masses which enclose the Indian Ocean, but they exhibit so many local modifications that no exact account can be given of them in our small compass.

Zone of Calms and Variable Winds.—In the Atlantic and Pacific Oceans, immediately under the equator, where the N.E. and S.E. trade-winds approach each other, there occurs a zone of calms and variable winds; there being a calm when the opposing winds wholly neutralise each other, and a wind, which is usually from the east, when either predominates. This zone varies in breadth from 150 to 500 miles, according to the season of the year, and is perpetually shifting its position. In March and April it extends from lat. 2° N. to 7° N.; in July and August from 7° N. to 12° N.; thus ranging over 10° of latitude. As each of the trade-winds has traversed a great extent of ocean before arriving at the equator, it becomes highly charged with vapour; and hence this zone is characterised by *constant precipitation*, the rain falling at irregular intervals and at all hours of the day. The heat is great, and thunderstorms are frequent; and perhaps there is no part of the ocean more dreaded by mariners than the zone of calms and variables.

Region of S.W. and N.W. Winds.—We have seen that the heated air of the Torrid Zone, forced upwards by colder and denser currents, finds its way to the Frigid Zones. On quitting the tropics it begins to cool, and consequently to descend, arriving at the surface about the 30th parallel of latitude in both hemispheres. Were the earth stationary, and were there, also, no opposing current from the polar regions, it is obvious that south winds would prevail over the entire N. Temperate Zone, and north winds over the S. Temperate Zone. But the earth rotates from west to east, and the wind, on its way from the tropics to the poles, is ever arriving at zones

of surface possessed of less rotatory velocity than itself; and it will therefore, so far as this cause is concerned, manifest itself as a *west* wind. Combining, now, both these causes, the resulting effect is that in the N. Temperate Zone S. W. winds must prevail, while in the S. Temperate Zone N. W. winds will predominate. Both these winds, however, are subject to great irregularities, mainly owing to their being affected by the great polar ocean-currents that are ever proceeding from the poles to the equator. The winds which result from such collisions must necessarily take a *mean* direction, depending on the relative force of the opposing currents; but this direction, though very variable, is chiefly *westerly*. In the North Atlantic they are chiefly from the S. W.; and the effect is, that a sailing vessel which takes forty days from Liverpool to New York can make its return voyage in twenty-three days. South of the equator, between the parallels of 40° and 50°, the winds are pretty regular, being generally W. N. W.; while in the N. Frigid Zone no regular succession has been observed, but northern winds are the most frequent.

Land and Sea Breezes.—On islands and near the shores of the continents, especially in warm and tropical regions, the wind during the day blows from the sea, while during the night it pursues a contrary direction. After the explanations given above, the cause of this becomes sufficiently obvious. The sea and the land are very unequally heated by the solar beams. About sunrise and sunset the temperature of both is nearly equal, and there is consequently no wind either way; but shortly after sunrise the land becomes warmer than the water, in consequence of the more powerful action of the solar rays; the temperature of the stratum of air next the surface is increased and its density lessened; it must therefore ascend to the upper regions of the atmosphere, leaving behind a vacuum, which is immediately occupied by colder and denser air from the ocean. Thus is originated a *sea-breeze*, which attains its greatest velocity at the period of the maximum heat of the day, and gradually declines towards evening. During night, when the temperature of the sea exceeds that of the land, the current of air must necessarily flow in an opposite direction, and produce what is called the *land-breeze*.

Hurricanes and Cyclones.—These originate in portions of the tropical zone, generally in the belt between the N. E. and S. E. trade-winds, and differ from each other only in degree. They seem to rotate around an area of *low pressure*, and to advance in continually widening spiral curves. Their rotatory movement is from 80 to 100 miles per hour, but the rate of progress from one region to another is, at greatest, only about 15 miles per hour. Indeed, the more violent the cyclone, the slower is its rate of travel. These storms are most frequent in the west of the North Atlantic, especially in the W. Indies, in the Indian Ocean, and in the Chinese Seas (where they are known as *Typhoons*), but there is perhaps no part of the globe altogether exempted from them. In the S. hemisphere they rotate in the same direction as the hands of a watch, but in the northern, in the

contrary direction. In tropical regions they are most destructive, and are greatly dreaded by mariners, but their danger lies in the fury of their rotation and not in the speed of their progress. When the storm approaches the shore, a wave is hurled on the land with disastrous effects, as in the Bay of Bengal, where it causes destructive inundations in the Ganges and Brahmaputra. They are attended by heavy falls of rain and frequent electric displays. In our country the approach of such storms is not indicated so much by lowness, or a sudden fall in the barometer, as by a great difference of pressure at places not far removed from one another. They almost invariably come to us from the Atlantic, and their arrival on the west coast of Ireland can be announced by telegraph before they have reached the other parts of our islands.

Aqueous Vapour and its Results.—The quantity of aqueous vapour in the atmosphere, which is always very small, varies with the temperature, being greater when the temperature is high, and smaller when it is low. Sir John Leslie showed, by numerous experiments, that the air can hold the 160th part of its own weight of vapour in suspension when its temperature is at 32° Fahr.; the 80th part of its weight at the temperature of 59°; the 40th part at 86°; the 20th part at 113°; and the 10th part at 140°. Seas, rivers, lakes, and moist ground are the sources from which the vapour in the atmosphere emanates. When water is thus passing from the liquid into the gaseous or invisible form, it is said to *evaporate*. Evaporation takes place at all temperatures, and is caused chiefly by the action of winds and of the solar heat on the surface of the earth; and the more intense this action is, the greater becomes the quantity of moisture that rises into the atmosphere. When the air has received as much vapour as it is capable of holding in the invisible form at any given temperature, it is said to be *saturated*. Should any more vapour enter it at this temperature, or should its temperature be reduced to any extent, the superabundant vapour instantly becomes visible and assumes the form of mist or clouds, or is precipitated as dew, hoar-frost, rain, snow, or hail. Should the reduction of temperature take place at a considerable elevation above the surface of the earth, by means of a cold current of air coming in contact with a warmer one already at the point of saturation, clouds will be the form which the superabundant vapour will assume; but if the reduction takes place at a lower level, so that the cloud rests on the ground instead of floating in the upper regions of the atmosphere, it is called a *fog* or *mist*. A difference between the temperature of two counter ocean currents, or between the water of a river and the air above, frequently causes fogs. Clouds and mist are identical in their nature, and only differ in respect to elevation; for in each of them the vapour, formerly invisible, is supposed to pass into the form of minute, visible globules, which, from being hollow within, are possessed of such buoyancy as to be capable of floating in the atmosphere. When the surface-temperature of the ground has been reduced by radiation, so that the air in contact with it falls below its point of saturation, a portion of the vapour contained in the latter

becomes condensed, and assumes the form of dew; and when the radiation has proceeded so far as to reduce the surface-temperature below the freezing-point, **hoar-frost** is the product. The quantity of dew, however, which is deposited on any given object, depends not only on its temperature, and on the amount of moisture in the air, but in a great measure also on the nature of its materials, its texture, and the roughness or smoothness of its surface. Thus, while metals, stones, and wood are found comparatively dry, living plants of every form are copiously laden with dew: substances having a close texture are unfavourable to its formation, while those that are loosely compacted, as cloth, wool, down, cotton, &c., are highly favourable; and those surfaces which part with their heat least readily, as, for example, polished metals, contract the least dew; while those that part with their heat most readily—viz., roughened or painted surfaces—contract the most. When the temperature that has led to the formation of the minute hollow vesicles of which a cloud consists has been reduced still lower, the vesicles become larger; then unite in twos and threes; and ultimately, by reason of their density and increased gravity, fall to the ground in large drops of **rain**. When the vesicles have been exposed to an intensely cold current of air, they are congealed or solidified into minute, icy crystals; and when many of these collect together, they usually assume a highly symmetrical and beautiful shape before descending to the earth in the form of flakes of **snow** (p. 84). Should the snow-flakes, in descending towards the surface, pass through a warm stratum of air, they melt and become **rain-drops**; and, on the other hand, should the rain-drops, while descending, pass through a stratum of very cold air, they are converted into **hailstones**.

Water and its various Forms.—All the above, together with steam and ice, are the various forms in which water is found in nature. No other substance assumes so many forms as water, none plays so conspicuous a part in the grand phenomena of nature, and none will better repay the most attentive consideration. Water may be defined as a transparent liquid; destitute of taste or smell; colourless when in small quantities, but of a bluish or greenish tinge when in large; absolutely necessary to the life of plants and animals; and more generally distributed in and over the crust of the earth than any other substance. In regard to **composition**, pure water consists of the union of two gases, oxygen and hydrogen, not simply *mixed* together, like the components of atmospheric air, but *chemically combined* in the proportion by weight of eight to one; but as found in nature, it invariably contains minute quantities of various mineral or other ingredients—as air, carbonic acid, nitrogen, silica, alumina, and numerous other salts. In regard to density, it is employed as the most convenient standard by which the specific gravity of all solids and liquids is computed. One cubic inch of pure water at the temperature of 62° Fahr. weighs 252 grains. Hence it is 13½ times lighter than mercury, and 814 times heavier than dry atmospheric air at the same temperature and at the average pressure. At 212° Fahr. it boils and passes off into **steam**, which occupies about 1800

times the volume of water. At 39°.2 Fahr. it attains its maximum density; while at 32° it freezes, expands, and becomes ice, a transparent solid, of vitreous lustre, of a sp. gr. of 0.918, which therefore floats on water, having $\frac{1}{8}$ of its bulk under the surface and $\frac{7}{8}$ above. As the usual density of sea-water is 1.0275, a larger portion of the ice (about $\frac{1}{2}$) remains above the surface than in the case of fresh water.

Clouds.—In addition to what we have said as to the nature and origin of clouds, we have to consider their different forms, height, and velocity.

Forms of Clouds.—The infinite variety of clouds seen covering the face of the sky can all be reduced to seven forms, three of which are simple and four composite.

1. *Cirrus* (from Lat. *cirrus*, a curl), formed of light-coloured slender filaments, pencilled on an azure sky, resembling the tresses of a lady's hair, or an entangled skein of wool. Being formed at a great elevation, where the atmosphere is far beneath freezing-point, they are regarded as consisting of minute ice-crystals. They are the least dense and the most elevated of all clouds, and though they often accompany serene weather, are supposed to be valuable indications of a breeze. In equatorial regions they are found stretching from north to south; but in higher latitudes they extend from north-west to south-east, while in the Arctic regions they form what are known as "mackerel skies," in which haloes and mock-suns so frequently appear.

2. *Cumulus* or *Summer Clouds* (from Lat. *cumulus*, a heap) sometimes resemble huge rounded masses of smoke or foam piled atop of each other, while at other times they are like the summits of distant snow-clad mountains. They are formed by ascending currents of the atmosphere, which, on attaining a higher elevation, cause the previously unseen vapour to become suddenly visible. They form the characteristic cloud of the day, appearing soon after sunrise, ascending as the day advances, and either vanishing towards evening (which is a prognostic of settled weather) or merging into the rain-cloud.

3. *Stratus* or *Fall Cloud* (from Lat. *stratus*, a layer), which arranges itself in long horizontal layers, is the lowest of all clouds, and is seen commonly resting on, or creeping along, the surface of the ground. As the last form described was the *day-cloud*, so this is the *cloud of night*, being formed by the descent of higher clouds as the surface of the earth becomes cooler after sundown. Should it not disappear with the morning sun, rain may be expected.

4, 5, and 6. — *Cirro-stratus*, *Cirro-cumulus*, and *Cumulo-stratus* are combinations of the preceding, for the particulars of which we must refer to works on Meteorology.

7. *Nimbus* or *Rain-Cloud* (from Lat. *nimbus*, a shower) is denser than any of the others, and is of a dark leaden hue, changing into grey. It is, in fact, a shower seen in profile as it approaches the spectator from the horizon.

Height of Clouds.—The elevation of clouds is very various, some of them almost resting on the ground, while others have an altitude superior to that of the highest mountain-summits, that of the *Cirrus* ranging from 3 to 10 miles. Prof. C. Piazzi Smyth, while living on Tenerife, frequently noticed a bank of cloud drifting with

a N.E. wind at an elevation of 4500 ft., and another, 15,000 ft. high, moving in an opposite direction. Clouds in Britain ascend to elevations of from 2000 to 6500 feet. They are highest in tropical latitudes, least in the polar regions, while in the interior of continents they are more elevated than near the ocean.

Velocity of Clouds.—The velocity of a cloud is the same as the velocity of the current of air in which the cloud is floating. But at different elevations in the atmosphere such currents move in widely different directions at the same moment, and thus the spectator often sees clouds right overhead veering towards different points of the compass. Generally speaking, in such cases, the higher the cloud the greater the speed of the current containing it—the height of the cloud and its shadow on the earth forming the only means of ascertaining the speed of the current. From 70 to 110 miles an hour, or about double the rate of an ordinary express train, is not an unusual velocity. Sometimes a cloud on the summit of a lofty mountain appears to be stationary, although at the summit itself a strong breeze is blowing: in such cases the aqueous vapour touching the cold mountain-side becomes suddenly visible, remaining so until it is carried beyond the influence of the mountain, when it assumes its former invisibility—the permanency of such clouds being analogous to that of rivers, which, though ever appearing the same, are constantly changing their contents.

Distribution of Rain.—Both as regards amount and frequency, rain is the most capricious of all atmospheric phenomena; but though its distribution is much more liable to irregularities and extremes than temperature, yet the following generalisations, which can only be regarded as rough approximations, will be found useful:—

1. Rain is more abundant in tropical regions than under higher latitudes, owing to the rapidity of evaporation and the greater amount of aqueous vapour in the atmosphere. The annual average rainfall between the tropics is about 96 inches—the Old World being 77 and the New 115; while in the two temperate zones the average annual fall is only 36 inches—the Old World being 38 and the New 34.

2. The number of rainy days is greater the farther a place is from the equator. Within the tropics the number of rainy days is estimated at 80, while in the temperate zones the average is twice that number.

3. The annual amount of rain decreases in ascending from low plains to elevated plateaux, as the winds are robbed of their moisture in their ascent: thus, while at Coimbra, in Portugal, the annual amount is 118 inches, and at Bilbao, 100; at Madrid, on the high table-land, it is only 10 inches.

4. On the contrary, the amount of rain increases in ascending from plains to the rugged slopes of mountain-chains. Thus, while in the great European plain it is under 20 inches, it is no less than 104 inches at Santa Maria, in the Alps.

5. The amount of rain decreases as we proceed from the shores of

continents towards their interior; thus, while on the W. coast of the United Kingdom, Norway, and Portugal, the annual average is from 80 to 150, 72, and 118 inches respectively, in Eastern Europe it is only 15 inches. Again, the number of rainy days decreases from 208 on the W. coast of Ireland to 90 in the basin of the Volga, and to 60 in the interior of Siberia. To this rule, however, there are important exceptions.

6. Mountain-chains act as condensers of vapour, especially when stretching across the path of warm, moist winds. On the side of the mountain which the wind strikes, the surface stratum of air is forced upward, depositing a large proportion of its vapour, while on the other side of the chain the current descends completely robbed of its moisture. The Andes, in South America, the Mts. of Norway, the W. Ghâts, in India, and Mt. Atlas, in N. Africa, afford striking examples.

7. The average annual rainfall for the whole globe is estimated at 60 inches.

8. Warm winds blowing towards colder climates bring rain, while cold winds advancing to warmer regions bring fine weather and drought.

9. The presence or absence of vegetation in any country has a great influence on the amount of rain deposited. A barren region, having nothing to shield it from the burning rays of the sun, becomes intensely heated, the temperature of the air increases, and its capacity for moisture is heightened, thus making the existence of rain impossible. A covering of vegetation, on the contrary, shields the soil from the sun's rays, keeps its temperature low, and promotes condensation.

Regions of Great Rainfalls.—The rainiest localities in Europe are Coimbra, in Portugal (where 118 inches fall annually), the Alps, Bretagne, and the west coasts of Norway, Great Britain, and Ireland. The average number of rainy days on the west coast of Britain is 208, on the E. coast 165. In some parts of Westmoreland and Cumberland 100 inches of rain fall annually; at Seathwaite, 6.62 inches have fallen in a single day; and at the Sty (which is believed to be the wettest spot in Gt. Britain), 38.9 inches have fallen in one month, while the annual amount is upwards of 200 inches. In Asia, the countries lying south of the great table-land are characterised by extreme moisture. The vapours borne by the S.W. monsoon are condensed on the W. Ghâts of India, and the rain falls in torrents along the west coast of that country. At Bombay, 16 inches have fallen in a single day, while at Mahabuleshwar, a sanatorium in the W. Ghâts, the annual fall is 254 inches, of which 242 fall during the four monsoon months. In the basin of the Brahmaputra the fall is also prodigious; in some places, as at Silhit, it amounts to 209 inches, while at Chirra Punji, among the Khasia hills, the greatest annual rainfall on the globe (615 inches) occurs. Between 16° N. and 20° S. lat. Africa is visited by copious periodic rains, brought by the monsoons from the Atlantic and Indian Oceans. These are, however, far more abundant on the coasts than in the interior. On some parts of the Guinea coast the fall is prodigious, and at Zanzibar it amounts to 167 inches annually. In the New World, the rainiest portions are Patagonia (where 109 inches fall annually), Chiloe, Valley of the Amazon, Florida, Iowa,

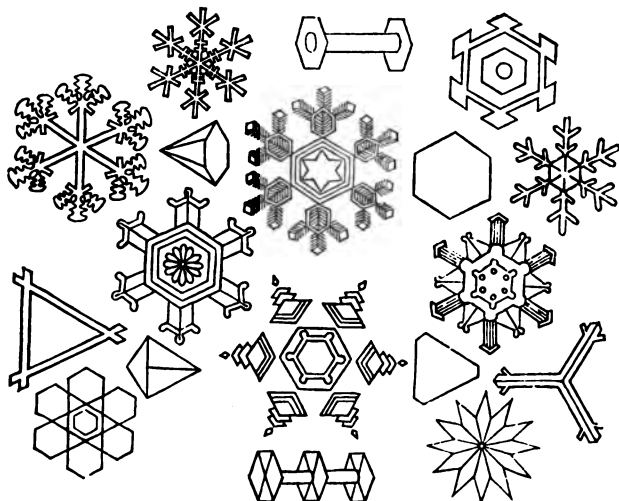
the low flats of the Mississippi, and the coast of British Columbia, while Sitka has an annual fall of 90 inches. In the "Doldrums" of the Atlantic (the belt between the trade-winds), the annual amount is 225 inches.

Rainless Regions.—Those of Asia are, the Great Desert of Gobi or Shamo, a large part of Biluchistan, Persia, Northern Arabia, and Southern Syria, in some of which a drop of rain is never known to fall, and in others only at long intervals and in very small quantities. In Africa, the great southern plateau is eminently dry; while in the Sahara, rain falls in torrents at very distant intervals, in some places not oftener than once in ten or twenty years. Even dew is here unknown, owing to the ascending currents of heated air which dissolve the vapours and disperse the passing clouds. The moisture brought by the trade-winds to the Australian continent is intercepted by the mountains bordering the eastern coast, so that the interior, from the 30th degree of S. lat. to within about 200 miles from the northern coast, is a dry cheerless desert. The rainless regions of the New World are, the immense tract lying between the Rocky Mountains and the 100th meridian, known as the "Plains," and the western highland, as the moisture which the Pacific winds should carry to them is arrested at the margin of the plateau by the Sierra Nevada and Cascade ranges: also the narrow coast region of Bolivia and Peru, known as the desert of Atacama, in some parts of which no rain has fallen within the memory of man.

Snow.—When the aqueous particles, produced by the precipitation of vapour, become frozen in their descent through the atmosphere into separate icy crystals, and afterwards unite together, the assemblages of crystals constitute flakes of snow. About 1000 different varieties of snow-flakes have been observed, which are generally of exquisite beauty and symmetry, especially in the polar regions, where the highest perfection of form is seen; although they are much larger in mild than in very cold weather. Captain Scoresby has reduced all the forms of snow into five classes, the most common presenting the outline of a hexagon or six-angled star (see "Aqueous Vapour and its Results," p. 79).

Height of Snow-line.—In all latitudes the tops of high mountains are covered with a layer of permanent snow which the summer heat is insufficient to melt. The lower limit of perpetual congelation is called the snow-line. In tropical regions its elevation is about 3 miles above the sea-level, in temperate latitudes it occurs at the height of 2 miles, while at the northern limit of the three northern continents it is about half a mile high. In the islands of the Arctic Ocean, vast fields of snow remain permanent during the year at an elevation of a few hundred feet. Thus the snow-line in both hemispheres attains its maximum elevation in the sub-tropical zone, and gradually descends, though the precise rate in proceeding to either pole is not yet ascertained. The highest known limit is on the north side of the Himalaya and the western side of the Andes of Bolivia, in both of which it attains an elevation of 18,500 ft.; on Kilimandjaro, East Africa, 17,000 ft., Mont Blanc, 8500 ft., Cen-

tral Norway, 4000 ft., North Cape, 2300, while at Spitzbergen (lat. 78° N.) it descends to the level of the sea. In the southern hemisphere the line of perpetual snow recedes from the pole much further



Snow-flakes.

than in the northern, as it touches the sea at lat. 54°, a latitude corresponding to that of Yorkshire. The height is not regulated exclusively by the degree of latitude, but depends very much on the elevation and exposure of the place, the character of the prevailing winds, the temperature and dryness of the air, and the depth of the snow that has fallen during winter. The quantity of moisture determines the *amount of precipitation*, being greater in the coast regions exposed to moist winds, than in the dry heated plateaux of the interior of the continents; the annual fall is greater also in cool-temperate latitudes than in the polar regions. The number of days on which snow falls increases with the distance from the limit of snowfall; thus, Malta is never visited by snow; at Gibraltar it is rare; at Palermo it falls on 1 day annually, at Rome 2, Venice 5, Paris 12, Copenhagen 30, and at St Petersburg 170.

Hail.—Hailstones usually present the appearance of partially melted snow-flakes that have been suddenly congealed by intense cold, and which become surrounded by a coating of ice radiating from the centre. As showers of hail are almost invariably preceded by thunder, they have come to be regarded as an electrical phenomenon. When a discharge of lightning occurs between two clouds, the oxygen along

the course of the flash is suddenly consumed in whole or in part, causing a momentary vacuum along a narrow line, or at least an extreme dilatation. The instantaneous effect of such dilatation is intense cold, which suddenly congeals all surrounding moisture. Showers of hail occur more frequently in spring and summer than in winter, and in southern Europe than further north. They usually travel in narrow parallel lines, and sometimes with destructive effects. The great hail-storm which occurred in France, in 1788, and caused irreparable damage to fruit-trees and vineyards, travelled from the W. Pyrenees to the Baltic, a distance of 600 miles, in two parallel lines, 8 m. asunder and 4 m. wide, some of the hailstones being 3 inches in diameter. The storm travelled at the rate of 40 m. an hour, the fall lasting at any place along its line seven or eight minutes.

Glaciers.—These are among the grandest and most remarkable phenomena in nature. They consist of huge masses of ice (or of snow that has been partially melted by the heat of summer, but which has afterwards been congealed), which, quitting the higher level, descend far below the usual snow-limit, into the region of cultivation, overwhelming and carrying down before them rocks, soil, and trees. This descent is owing to the inclination of the bed, the annual accumulation of snow during winter in the higher levels, the viscous or semi-fluid character of the structure, and other causes. They advance most slowly in winter and most rapidly in spring and summer, but the rate of motion in the descent is different in different glaciers (in the Alps it is about 350 ft. per year), according as the elements just specified vary; but it is *continuous* though not *uniform* in all, never being wholly arrested, even during the most severe winters. As in a river, the velocity increases with the slope, while the surface and central parts move faster than the bottom and sides. In the same way, also, as a river carries off from a district its excess of water, the glacier drains the snow-fields of their excess of snow. The head-waters of the Rhine, Rhone, Po, and Danube find in the Alpine glaciers a never-failing supply of water, and these rivers, as also the lakes through which they flow, have high water in summer, when the melting of the snow and ice is most rapid. The most extensive glaciers in the world are those of Greenland—the interior of which is supposed to be one vast ice-field—from which huge glaciers (some of which, as the **Humboldt Glacier**, are 45 m. broad at the base, and from 300 to 500 ft. in height) extend to the sea-shore, sometimes, indeed, for two or three m. into the sea. They are also seen on a grand scale in the Himalaya Mts., whence they descend to 3000 ft. below the snow-line, and are common in the Caucasus, Pyrenees, Scandinavian Mts., as also in Iceland, Spitzbergen, the Rocky Mts., Columbian and Patagonian Andes, and the New Zealand Alps; but the most remarkable glacier region is that of the Alps, where there are said to be 1100 distinct glaciers, among which three groups are particularly celebrated. The first is that of *Mt. Blanc*, consisting of 34 enormous glaciers, and including the *Mer de Glace* which covers an area of 18 sq. m. and the *Glacier de la Brenva*, one of the most beautiful and most accessible of all known glaciers; the second group

is that of *Monte Rosa*, in which is the *Zermatt* or *Görner Glacier*, so well described by the late Swiss naturalist, Agassiz; while the third is the group of the *Oberland*, including the great *Aletsch Glacier*, which has an area of 32 sq. m.

Moraines are lines of rock, gravel, and rubbish on the surface of a glacier, which increase with its progress, and terminate in huge piles frequently from 50 to 100 ft. high; the accumulations at the end of a glacier being called *terminal moraines*, those on its sides *lateral moraines*.

Crevasses are fractures or fissures in the glacier, caused by its movement through an irregular valley; sometimes these chasms are 500 ft. wide.

Avalanches are accumulations of snow and ice, which are precipitated with destructive violence from the edge of precipices into the valleys below. They are the most dangerous and terrible phenomena of the Alpine valleys, and are also known in the Pyrenees and Norwegian Mts.

Icebergs.—In polar regions glaciers frequently descend for some distance into the sea, where they lose their support, and vast masses are floated away as icebergs. Of these Greenland is the great nursery, and from it the cold Davis Str. current brings down annually about 400 bergs, many of them 250 ft. above water, measuring miles in circumference, and loaded with stone and shingle. Many of them lodge on the Grand Banks of Newfoundland, where they are either melted by the Gulf Stream or are broken up by the sea; while others beset the offings of the Canadian harbours, and occasionally reach as far as 40° N. The bergs of the Antarctic Ocean are sometimes 300 ft. high, and frequently travel as far north as the apices of the continents. Icebergs assume the most fantastic shapes, and are greatly dreaded by mariners, not only on account of the risk of collision, but because they sometimes suddenly explode into a thousand pieces, while at others they lose their equilibrium and topple over, causing great disturbance in the surrounding ocean. As the specific gravity of ice is 0.918 (at 32° Fahr.), only about $\frac{1}{8}$ of the mass usually rises above the level (see p. 81).

Ice-fields.—The surface of the polar seas is frozen wherever the temperature is below 28° Fahr. (the point at which sea-water freezes). Snow falling on this cannot melt, so that a thick coating of ice and snow is speedily formed. This ice is most closely bound together in the winter months. June, July, and August are the *open months* of the Arctic Ocean, and December, January, and February those of the Antarctic. Immense tracts of this frozen surface are called *ice-fields*, and when the warm weather and the winds cause these to break up and drift together, so as to become piled up in immense masses, such accumulations are termed *packs*. Smaller masses of floating field-ice, of about a quarter of a mile in circumference, are called *floes*. As has been stated above, the ice of the Antarctic Ocean occupies three times the extent, and stretches 10° nearer the equator, than that of the Arctic basin. Its floes and bergs are also much greater, and the perpendicular barriers of ice which guard its inhospitable shores

are nearly double the size of the ancient ice-cliffs which bound the American side of the Arctic Ocean, from the coast of Alaska to the head of Smith Sound, in lat. $83^{\circ} 20'$ (see under "Arctic and Antarctic Oceans").

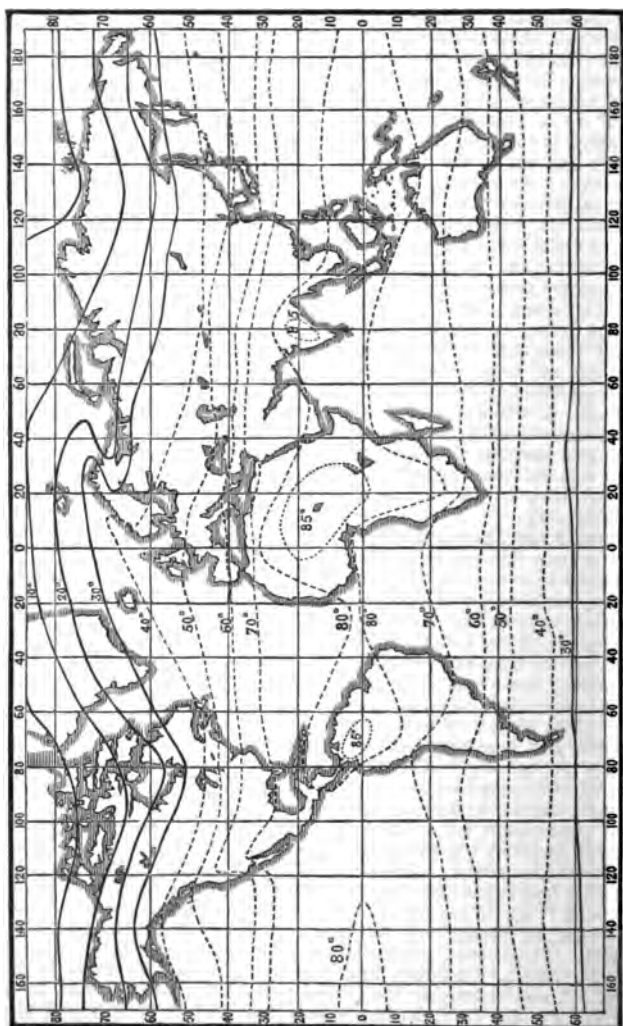
VI.—CLIMATE.

By the climate of a place is meant the prevailing character of its weather, or all those states and changes of its atmosphere which sensibly affect the organs of plants and animals. The peculiarities of climate are mainly attributable to the following causes :—

1. **Latitude.**—This determines the amount of solar heat which the place enjoys—which amount depends, not merely on the length of time it is continuously exposed to the solar rays, but especially on the direction of the rays when the sun is in the meridian. Between the tropics the solar rays descend vertically at noon, and hence produce their maximum effect; but the more remote the place is from the torrid zone the rays descend more and more slantingly. 2. **Elevation.**—The more elevated any place is, the lower is its temperature; and a change of level of only a few feet will diminish the temperature of the place as much as a change of latitude amounting to many miles. In the torrid zone an ascent of 333 feet sinks the thermometer 1° Fahr.; but the rate is not uniform as the ascent is continued—less than 333 feet being sufficient for reducing the temperature another degree. A smaller elevation will also suffice for producing this effect in higher latitudes. By continuing the ascent in any latitude, we at length arrive at what is called the **snow-line**, or the **limit of perennial congelation** (see p. 84). 3. **Slope or Aspect** at noon greatly affects the climate of a country, especially in the temperate zone. If the slope is towards the sun at noon, the rays of that luminary fall more directly on the surface, and therefore produce a greater effect than if the place is level; while, on the other hand, if the surface inclines towards the north, the contrary effect is produced. Thus, in Siberia and British America, where the slope is northward, as indicated by the direction of the rivers, the climate is incomparably more rigorous than in the British Isles and Scandinavia, though situated between the same parallels of latitude. In the south of Siberia mercury freezes in winter; whereas in Ireland the myrtle grows in the open air. Even in the same locality the greatest diversity of climate prevails on the opposite sides of a mountain-range. Thus, on the southern slopes of the Alps of the Valais the vine attains to its utmost perfection, while the northern slope is densely covered with ice and snow. 4. **The Situation of a Country in respect to Large Tracts of Land or Water.**—The temperature of the ocean is more equable than that of the land, being less affected by the action

of the solar rays and by radiation. Hence, through the agency of the winds, those countries which are situated near the ocean are less subject to the extremes of heat and cold than other countries under the same latitude situated in the interior of continents. Thus London enjoys a milder winter and a cooler summer than Paris, which is $2^{\circ} 42'$ of latitude farther south. In the northern hemisphere a country is rendered hotter by having a large tract of land to the south and sea to the north, but cooler when these relations are reversed. 5. Climate depends, also, on the **prevailing direction of the winds**, and whether they come from the land or from the water. Thus, the east winds of the British Isles, in spring, come from Siberia and Northern Russia—*i.e.*, from the coldest part of the Old World, in the coldest month: they contain little or no moisture, and though they ultimately traverse the North Sea, their temperature is too low to absorb vapour. Hence, for three months of the year they are peculiarly trying to invalids, especially on our E. coasts. Our south-west winds, on the other hand, come from the Atlantic and Gulf Stream, and bring with them great quantities of moisture: hence the average fall of rain is much greater on our western than on our eastern coasts. 6. Other important elements of climate, such as proximity to **ocean-currents**, the **annual fall of rain**, and the **direction and relative position of mountain-chains**, together with the **nature of the soil** and the **degree of cultivation** to which it has been subjected, have for the most part been treated of in previous sections of this work.

Isothermal Lines and Climatic Zones.—As the temperature of any given place depends on a multitude of causes besides latitude, it is obvious that the old designations of *torrid*, *temperate*, and *frigid zones*, bounded by the tropics and the polar circles, do not adequately express the temperature, and far less the general climatic character, of the different parts of the earth's surface. Humboldt and others have accordingly substituted other lines, instead of the parallels, as the true boundaries of climatic zones—*viz.*, *Isothermal*, *Isocheimal*, and *Isothermal lines*. The mean annual temperature of any given place may be readily ascertained by means of the thermometer; and imaginary lines connecting together all the places in the same hemisphere, having the *same mean annual temperature*, are called *Isotherms* (*isos*, equal; *therme*, heat). The *Isocheimals* (*isos*, equal; *cheima*, winter) are similar lines connecting places that have the *same winter temperature*, and the *Isothermal lines* (*isos*, equal; *theros*, summer) are those drawn between places having the *same summer temperature*. These lines of equal temperature approximate, more or less, to the direction of the equator, though they are nowhere parallel to it. They diverge from it more in the northern than in the southern hemisphere, and greatly more in high than in low latitudes. The hottest portion of the earth's surface in July is a tract in N. Africa, extending from the meridian of Greenwich to E. lon. 75° , and embracing the central part of the Red Sea and head of the Persian Gulf, having a July temperature of 95° ; and the coldest winter temperature, so far as yet ascertained, is an oval tract



ISOTHERMAL LINES, SHOWING THE MEAN ANNUAL TEMPERATURE OF THE GLOBE.

around Yakutsk, in Siberia, with a January temperature of $-41^{\circ}.4$, and a July temperature of $63^{\circ}.3$, showing a difference between the summer and winter temperatures of $104^{\circ}.7$. It appears, therefore, that the hottest region is not under the equator, nor the coldest under the pole; and that all the lines of equal temperature in the northern hemisphere attain their highest latitude in the eastern side of the Atlantic Ocean—owing, no doubt, to the high temperature of the Gulf Stream, which flows northward along the western shores of Europe. The isocheimal of 40° passes through the centre of the British Isles in January. In July they are traversed by the isothermal curve of 60° , while the isotherm of 50° expresses the mean annual temperature. Our *yearly range* is about 20° , while that of Central Asia in the same lat. is not less than 85° . By means of these isotherms each hemisphere is divided by the meteorologist into six climatic zones, named respectively the *hot* or equatorial, the *warm*, *mild*, *cool*, *cold*, and *frigid* or polar zone.

The **Equatorial Zone** extends on both sides of the equator, is bounded by the isotherms of 77° , and embraces Central America, the West India Islands, a portion of South America, all Africa between the Atlas chain and the 15th degree of S. latitude, and the north of Australia. The **Warm Zone** is bounded on the south by the equatorial zone, and on the north by the isotherm of 59° , which, in the New World, passes through San Francisco and Cape Hatteras; and, in the Old World, through the north of Spain, Rome, Gallipoli, the north of Asia Minor, the south of the Caspian, Lake Koko-Nor, the mouth of the Hoang-Ho, and the capital of Japan. The **Mild Zone** is bounded on the south by the warm zone, and on the north by the isotherm of 41° , which passes through the Aleutian Islands, Sitka, a little south of Lake Superior, through the centre of Nova Scotia; and, in the Old World, through Bergen, Christiania, Stockholm, Riga, Moscow, and Orenburg. The **Cool Zone** is bounded on the north by the isotherm of 32° ; which, in the New World, passes Cape Romanzoff, Cumberland House, and the southern extremity of James Bay, south of Nain in Labrador, and north of Cape Farewell in Greenland; and, in the Old World, through the north of Iceland, Hammerfest, head of the Gulf of Bothnia, Archangel, Tobolsk, and the south of Lake Baikal. The **Cold Zone** is bounded on the north by the isotherm of 5° , which passes through the centre of the North American Archipelago, north of Greenland, and through the extreme north of Siberia. And, lastly, the **Polar Zone**, whose southern limit is the isotherm of 5° , embraces all the remainder of the Arctic regions.

Isobaric Lines.—In studying the character of the weather and the direction of the winds in any locality, it is of the utmost importance to determine the variations of atmospheric pressure to which the locality is subject at the different seasons of the year. In January, the highest barometric pressure occurs over the continents of the N. hemisphere, especially over northern and central Asia, where in some places it amounts to 30.4 in.; it is important to observe that this is also the region of the greatest winter cold; while the lowest pressures, in January, are distributed over the higher latitudes of the oceans

of the N. hemisphere, and over the Antarctic Ocean. "Since the winds on the earth's surface everywhere flow out of this region, the inference is inevitable that the sources of this high mean pressure can only be in upper currents flowing towards it and over it from the four regions of low pressure lying respectively to the E., the S.E., the S., and the W. It is this low pressure in the N. Atlantic, together with the high pressure over central Asia, which forms the key to the winter climates of Europe." — *Buchan*. The average barometric pressure of the British Isles, in January, is 29.7. In July, on the other hand, the lowest pressures are distributed over the N. continents, together with N.E. Africa; and the highest pressures over the ocean between 15° to 50° N. lat., and in the S. hemisphere over the entire zone extending from 10° to 40° S. lat. The mean barometric pressure in the British Isles in July is 29.9. Lines connecting places of the same mean pressure are termed isobaric lines (*isos*, equal; *baros*, weight), and are usually of a three-fold character—viz., those connecting places of equal pressure in January, July, and the entire year. They are of the greatest importance in the study of meteorology—as, for example in understanding the direction and strength of the wind: the closer the isobaric lines are, the stronger the wind; and the further apart, the lighter.

VII.—ELECTRICITY AND MAGNETISM.

These mysterious forces, now believed to be closely allied, are known to be so vitally concerned in many of the grandest and most intricate phenomena of nature, that even in so brief a treatise as the present some notice must be taken of them.

Electricity.—This force is found to penetrate all nature. The simplest way of producing it is by friction. When any two bodies, as wax and flannel, are smartly rubbed against each other, electricity is produced. Take a stick of sealing-wax and rub it with a woollen cloth: then hold the wax above small slips of paper lying on the table; they will suddenly fly from the table and adhere to the wax. After remaining in this position for a little time they will be repelled and fly away. It was amber, and not wax, that was first employed in producing this curious phenomenon. Indeed, for more than 2000 years the attraction of light bodies by amber was the sum of human knowledge regarding electricity, and hence the name of electricity (from *electron*, amber). There are two kinds of electricity, the one known as *vitreous* or *positive*, the other as *resinous* or *negative*. When two substances are rubbed against each other, the one is invariably charged with the *positive* form, the other with the *negative*. Such two bodies always attract one another, but two bodies exhibiting the same kind of electricity repel each other. The chief sources of this force are friction, pressure, combustion, evaporation,

and condensation; while its principal effects are attraction, heat, light, chemical action, and magnetism. With respect to electricity, all substances may be divided into two great classes, conductors and non-conductors. To the former belong the metals, carbon, vegetables, animals, earths, water; and to the latter, amber, glass, silk, leather, and atmospheric air. There is a constant tendency in electrified bodies to render themselves neutral, by drawing electricity of the opposite kind from some neighbouring body that possesses it. As the electric fluid is confined to the *surface* of bodies, this neutralisation is the more readily effected when the bodies are pointed or angular. Should the two bodies be separated by a bad conductor, as dry air, the fluid, if intensely developed, may force its way through the air, but a vacuum forms an effectual barrier. When the electricity is sufficiently accumulated, a spark is produced, called the electric spark, which is accompanied by an audible report. **Lightning** is the dazzling light produced by an electric discharge passing between clouds that are oppositely electrified, or between a cloud and the ground. This was clearly shown in 1752, by Dr Franklin, who, by means of a kite, succeeded in obtaining a spark from a thunder-cloud. The atmosphere, when dry, is in general positively electrified; but any disturbance in it produced by heat, evaporation, condensation, or any other cause, will produce a change in its electrical condition. It has been ascertained that the earth is uniformly negative. Hence if a cloud charged with positive electricity passes within a sufficient distance of the earth, lightning is produced. In this case the electric fluid rushes from the one cloud to the other with inconceivable force and velocity; heat is thus produced of so intense a character that it burns up the portion of air through which it passes; the air from either side rushes in with great force to fill the vacuum; a great vibration of the atmosphere ensues, producing a sound familiarly known as **Thunder**. Thunderstorms are greatly more common and terrific in tropical than in temperate countries, as the heat is more intense and evaporation more rapid. For the same reason, they are most frequent in summer in higher latitudes. As the electricity of salt water is positive, or the same as that of the atmosphere, they are less frequent at sea than on land. Such storms ordinarily take place at an elevation of about 3000 ft., though they have been observed at the height of 16,000 ft. The height may be ascertained by observing the interval that elapses between the moment at which the spectator sees the flash and that at which he hears the report; as, for short distances, the passage of light is practically instantaneous, whereas sound-waves travel at the rate of 1130 ft. per second. Thus, if five seconds be the interval, the electric cloud is about one mile distant. Electricity may be conveyed to any distance, either by land or along the bed of the ocean, by means of suitable conductors. **The Submarine Telegraph** between Valentia in Ireland and Newfoundland, affords a striking example. This cable, 1866 m. long, consists of several plies of copper wire firmly twisted together and protected by a coating of gutta-percha. By means of this cable, the velocity of electricity along

submerged wires was ascertained to be 14,000 m. per second, which is only $\frac{1}{17}$ the velocity of light. This difference is probably due to the fact that electricity, in its passage through long wires, induces a *counter-current*, which must retard its progress. Wheatstone found long ago that the rate of *frictional* electricity is 288,000 m. per second.

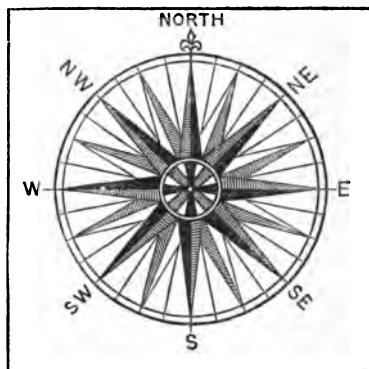
Magnetism is another very remarkable force, pervading all nature. In some of its phenomena it closely resembles electricity, but in others it greatly differs. The term *magnetism* is derived from a mineral called the loadstone (an oxide of iron) which abounded in *Magnesia*, in Asia Minor, and was known to the ancients. It is an iron ore which possesses the peculiar characteristic of attracting iron and steel, and of assuming, when freely suspended, a north and south position. This property (called *polarity*) it can temporarily communicate to a bar of soft iron by contact, or permanently to a bar of steel, which thus itself becomes a magnet. The ends or poles of the steel bar will now powerfully attract iron, the middle of the bar being neutral; if freely suspended, it will assume a direction nearly parallel with the meridian; its northern extremity will strongly attract the southern extremity of another magnet, but will violently repel its northern end. In all these respects magnetism resembles electricity, but it differs from it in various important particulars: thus, its attraction and repulsion are permanent; its attraction is not confined to the surface of bodies; it cannot, like electricity, be insulated by a non-conductor, as it passes freely through any intervening substance; while its attraction is confined (at least perceptibly) to a very few substances. The last-mentioned difference is, however, more apparent than real; for a powerful magnet will attract not only iron, but also cobalt, nickel, platinum, palladium, manganese, &c., and will repel antimony, bismuth, copper, lead, silver, and mercury. Indeed, all substances in nature are more or less affected by magnetism. The earth itself is in reality a vast magnet, having two magnetic poles, which are not coincident with the astronomic poles of the planet. There can be little doubt that it is this magnetism of the planet that imparts polarity to the loadstone, for it is to the *magnetic* poles of the earth, and not to its *terrestrial*, that a freely suspended magnetised needle points. To impart polarity to any substance is to cause the minute particles of which it is formed to assume a regular symmetrical position, their similar faces or ends always looking in the same northerly direction, each particle thus becoming a true magnet. When a bar of iron is magnetised, it is found that its length has slightly increased at the expense of its thickness, thus showing that all its particles have altered their former position. The particles were not in *absolute* contact before being polarised, though the body was solid; nor are they in absolute contact yet, for the bar will still contract by cold and expand by heat in all directions. Indeed it is questionable whether any one atom of matter ever yet came into absolute contact with any other. The magnetic poles, to which a magnetised needle points, are not stationary, but move slowly in a circular curve, which they complete, according to Mr R. A. Proctor, in 650 years. This motion is analogous to that of the

polar axis of the earth, which, instead of pointing invariably to the same star, gyrates around the true pole of the heavens in 25,868 years. The magnetised needle follows the magnetic pole in this secular revolution, and is in fact the best index of its position at any given time. The exact position of the north magnetic pole was determined by the late Sir J. C. Ross, in 1833, as in lat. 70° N., lon. 97° W.,—a point situated in Boothia peninsula; while the southern magnetic pole was approximately determined by the same navigator, in 1841, as in lat. 75° S., and lon. 145° E. At Greenwich Observatory, in 1580, the needle pointed to $11^{\circ} 15'$ E. of N., at which time it was moving westward; in 1660 it pointed due N., and continued to move in a westerly direction till 1814, when it arrived at its maximum declination of $24^{\circ} 20'$ W. It then again began to move eastward, at an average rate of about $5'$ per year, its present declination at Greenwich being $19^{\circ} 15'$ W. The rate of secular variation is not uniform, but is greatest near the minimum of declination, and least near the maximum. Over a large portion of the earth's surface, the declination of the needle is *westerly*, while in all the remainder it is *easterly*. On a Mercator's map draw two lines, the first through the White and Caspian Seas to Bombay and the eastern boundary of W. Australia; and the second through Boothia peninsula, Washington, Cayenne, and Rio de Janeiro. All places between these lines of *no variation* have at present a western declination, together with a large, oval space in the east of Asia, including Japan and parts of China and Siberia. In all other parts of the earth the declination is eastern. Lines passing through places having the same declination are called *isogonal lines* (from *isos*, equal; *gonia*, an angle).

Magnetic Inclination, or Dip, is the constant departure of the needle when freely suspended from a horizontal position. In the N. hemisphere the northern pole dips or inclines downwards, while in the S. hemisphere it is the south pole that dips. The inclination is greatest at the magnetic poles, where the needle assumes a vertical position. Passing towards the equator, the inclination becomes less and less, until a line is reached in which the needle is horizontal. Lines connecting places where the dip is the same are called *isoclinals*, which coincide in a remarkable manner with isothermals, or lines of equal mean temperature on the globe, thus indicating a close connection between magnetism and solar heat (see p. 89). Magnetic inclination, like declination, is subject to secular variation. The dip has been decreasing ever since it was first observed in 1671. It was then, at Greenwich, 75° ; in 1820 it was $70^{\circ} 8'$; in 1868 it was $67^{\circ} 54'$; while in 1876 it was $67^{\circ} 42'$ —showing a rate of diminution of from $2'.8$, per year, to $1'.5$.

The Mariner's Compass.—This instrument, of such infinite importance to navigators, is merely a magnetic needle delicately balanced on a pivot, and fixed to the lower side of a circular card, on which is traced a star with the four cardinal points (N. S. E. W.) and the twenty-eight intermediate ones. The box enclosing the card is hung with the greatest exactitude, so as to insure its horizontality in spite of the ship's motion. This arrangement enables the helmsman to

steer his ship, whether by day or night, in fair or foul weather, in



Mariner's Compass.

any direction he pleases. Such an instrument was first employed by Europeans in the end of the twelfth century; but for land journeys it had been used by the Chinese and other Eastern nations at least 1000 years earlier.

The Aurora Borealis, or northern light, is now believed to be the combined effect of electricity and magnetism. This phenomenon consists of a luminous electrical meteor, highly magnetic, frequently seen by night in the northern part of the heavens, and at great eleva-

tions. It occurs in many forms, but the most common is that of a luminous arch, whose summit is in the *magnetic meridian of the place of observation*, and from which streaks of light are projected towards the zenith. From spectroscopic observations made by the "Scandinavian Polar Expedition," the aurora seems to be caused by the presence of minute particles of iron, carbon, and snow in the atmosphere. It varies in height from 40 to 160 miles above the earth's surface. In very high latitudes—as around Hudson Str.—magnificent auroras light up the heavens during the entire cheerless winter; and even as far south as Toronto, in Canada, they have been observed on 261 nights in the year. It is now ascertained that, simultaneously with the northern aurora, phenomena precisely similar, known as the *Aurora Australis*, appear around the south magnetic pole.

VIII.—BIOLOGY.

Biology (from *bios*, life, and *logos*, a discourse) is the science of existing life in nature, whether animal or vegetable, and embraces three subdivisions—botany, zoology, and ethnography.

1. **Botany** (from *botane*, an herb) is that branch of biology which treats of the form, structure, functions, distribution, and classification of plants. Unlike the animal, the vegetable kingdom belongs to one great type—the Radiate—which is subdivided into **Cryptogama**, or non-flowering plants (from *kryptos*, hidden, and *gamos*, nuptials),

comprising sea-weed, ferns, mushrooms, lichens, mosses, &c.; and **Phenogams**, or flowering plants (from *phainos*, open, and *gamos*, marriage), as the pine, maple, spruce, &c.

Number of Species.—The number of species presently known to botanists probably exceeds 120,000, of which 103,000 species are flowering plants, and 17,000 non-flowering; but the progress of discovery is so rapid, and the parts of the earth's surface still uninvestigated so extensive, that 200,000 appears to be a very moderate calculation of the number of species actually existing.

Antiquity of Species.—The geologist can demonstrate that all the species of the existing flora were not created simultaneously, but were introduced at successive stages as the surface and temperature of the earth became fitted for their reception. They are, therefore, of very different degrees of antiquity; for while they all appear to have been denizens of the earth ever since the creation of man, most of them were ushered into being prior to the time in which our existing continents acquired their present configuration; and a very few of them can be traced back to the earliest Tertiary ages. Those species are reckoned the oldest which combine simplicity of organisation with great width of distribution, as our common grasses and rushes, together with mosses, lichens, fungi, and ferns; while those that are confined to small areas—notwithstanding the contiguity of land having a suitable climate, and their being endowed with the requisite means of transport—are considered the most recent.

Centres of Creation.—Many are of opinion that all, or nearly all, the plants found in any particular locality, were originally created there. The great Swedish botanist, on the other hand, believed that the progenitors of all the existing plants were created in one particular region, from which they were gradually disseminated over the earth's surface. Innumerable facts can be adduced by modern science to show that each of these hypotheses is equally untenable; and most naturalists are now of opinion that there were numerous *specific centres*, situated in numerous and widely-separated localities, each centre being the birthplace of one species, or assemblage of species, which continues to grow there in greater perfection than in any other region to which, by the various transporting agents known to exist, it was subsequently wafted.

Modes of Dissemination.—Many plants are possessed of means by which they can diffuse themselves over areas more or less extensive. Some have seeds with winged or feathery appendages, which enable them to float on the air; other seeds are so small as to be borne by winds to distant localities; very many are transported by rivers, streams, marine currents, and even icebergs, to very remote regions, where, if the soil and climate be suitable, they take root and propagate their species; while not a few adhere to the hairy coatings of migratory animals, or, entering into the gizzards of birds of passage, retain their vitality after being voided by them in distant localities. The agency of man has also, in all ages, been very effectual in the dissemination of plants; for example, the passage of armies from one country to another, commerce by sea with foreign nations, the dis-

covery of previously unknown lands, and the planting of colonies in distant regions. But all these agencies, singly or combined, cannot adequately account for the present distribution of the species, without supposing a multiplicity of original specific centres.

Areas of Distribution.—In whatever way the vegetation of the globe was originally disseminated, its present distribution is such that the individual species are confined to particular portions of the surface characterised by a certain temperature and other climatic conditions. The area within which a given plant prevails is called its *habitat*, or *area of distribution*. In or near the centre of this area it attains its highest development; it degenerates when far removed from this centre; and when transported beyond the limits of the area, it languishes and dies. Though each species of plant has a nature peculiar to itself, the soil, temperature, and climatic conditions of the various portions of the earth's surface are so various, that each species finds for itself a perfectly suitable habitat. These habitats, or areas of distribution, are of all sizes; embracing in some cases a large section of a continent, or of several continents, and being limited in others to the merest speck of land. For example, a considerable number of plants of Northern Europe occur also in Siberia and British North America; some British species are found at high elevations on the Himalaya Mountains; and one species—the *Epilobium tetragonum*—is common to Britain, Canada, and Tierra del Fuego. On the other hand, the Cape of Good Hope, California, and certain regions of the Andes, have respectively certain species peculiar to themselves; as also Madeira, the Canaries, St Helena, the Sandwich and Society Islands, &c. The same species of plant seldom occurs in widely-separated countries, however closely the soil and climate of both may approximate; but *similar* species of the same genus are, in such circumstances, rarely absent, and these are spoken of by botanists as *representative species*. Thus the heaths of Europe are represented by other species of the genus *Erica* in S. Africa; and the violets of North America represent those of Britain, which are specifically different.

Botanical Regions.—Various attempts have been made by botanists to divide the globe into certain well-defined *regions*, founded on their characteristic vegetation. Willdenow, De Candolle, Meyen, and especially Schouw, have distinguished themselves in this department of science. The last-named naturalist, about forty years ago, proposed to divide the earth's surface into what he calls "Phytogeographic regions." These, according to him, are 25 in number, and will be found at length in the author's 'Manual of Modern Geography,' p. 54. Meyen, as modified by Professor Henfrey, divides the globe into eight zones bounded by mean annual isothermal lines. 1. **The Equatorial Zone**, or regions of palms and bananas, bounded by the isotherms of 79°.3 Fahr. on each side of the equator. 2. **The Tropical Zones**, or regions of tree-ferns and firs, bet. the isotherms of 79°.3 Fahr. and 72°.5 Fahr. 3. **The Subtropical Zones**, or regions of myrtles and laurels, bet. 72°.5 Fahr. and 68° Fahr. 4. **The Warm Temperate Zones**, or regions of evergreen dicotyledonous

trees, bet. 68° Fahr. and 54°.5 Fahr. 5. **The Cool Temperate Zones**, or regions of European dicotyledonous trees, bet. 54°.5 Fahr. and 41° Fahr. 6. **The Subarctic Zone**, or pine region, bet. 41° Fahr. and 36°.5 Fahr. 7. **The Arctic Zone**, or region of rhododendrons, bet. the isotherms of 36°.5 Fahr. and 41° Fahr. 8. **The Polar Zone**, or region of Alpine plants, bet. the mean summer temperature of 41° Fahr. and 36°.5 Fahr. (See pp. 30, 31.)

Vegetation in the different Continents.—Europe does not contain a single species of plant peculiar to itself; yet it is, together with the western half of Asia, distinguished for the number and variety of its vegetable products, more especially for those of the greatest use to man. Among Food-plants, the cereals are cultivated 20° further north in Europe than in America, while the potato forms a highly-relied staple article of food for millions of people from Iceland to Greece. Natural forests and fruit-trees abound in central and southern Europe, the vine extending to lat. 50°-53° N. No part of the world surpasses southern and south-eastern Asia in the number of its native fruits and esculent vegetables: here also is the natural habitat of many gums and resins, of medicinal and incense-yielding plants. Ornamental and dye woods are in endless variety, while the Eastern Archipelago is noted as being the "land of spices." In India and China, rice is extensively cultivated (one hundred varieties being produced in Ceylon alone) and forms the staple article of food for one-third of the entire human race. With the exception of the equatorial regions, Africa has a comparatively scanty flora; here, however, vegetation is luxuriant and gorgeous, though, so far as known, neither so rich in species nor so peculiar in form as in the other southern continents. Here also dense forests occur, but they are often interspersed with treeless regions, where tall grasses and shrubs are the only vegetation. North America is distinguished from the other northern continents by the immense size and great variety of its forest-trees and flowering shrubs.* The heath tribe of the Old World is nowhere found in the New, while on the other hand the entire cactus tribe is peculiar to America. Europe is indebted to America for maize, cocoa, manioc, potato, and tobacco; while America has received from us all the other species of corn, together with the sugar-cane, coffee plant, bread-fruit tree, and cotton plant. Owing to the great heat and wealth of moisture of South America, the vegetable kingdom attains there its greatest development. In the tropical region east of the Andes, the genera and species are not only more numerous than in any other portion of the globe, but the forests are more extensive, and the forms more gigantic. Cacao, manioc, caoutchouc, tobacco, and maize, are here indigenous; but wheat, rice, sugar, coffee, and cotton, have been introduced by Europeans. The vegetation of Australia is extremely peculiar; the native trees are all evergreens, and the forests consist chiefly of gum-trees, of which there are upwards of a hundred species. Many entire orders of plants occur only in this continent, but, on

* In the low-lying swamps of the Gulf States the trees are draped with grey moss, a beautiful parasite which is largely used in upholstery.

the other hand, it has scarcely an edible plant indigenous to it. The principal food-plants of Europe have been introduced with great success, while the vine, fig, orange, peach, and numerous other fruits flourish in the greatest luxuriance.

Range of Plants most useful to Man.—The geographical distribution of both plants and animals as shown in the previous pages, is mainly an affair of climate; and this holds true in an eminent degree with regard to those species which in all ages have most contributed to the welfare of the human race. It will therefore be interesting to survey the geographical range of the cereals and other food-plants; plants used for clothing; medicinal plants; plants employed for dyeing; and plants used for ornamental and other purposes.

Food-plants.—Food sufficient for the support of human life, either from the vegetable or animal kingdom, is found in all climes, but the materials employed vary exceedingly. In the Tropical Zone, the diet of the native man is almost exclusively vegetable, and is obtained from plants growing spontaneously. Chief among these are the bread-fruit tree, banana, cassava, manioc, date and sago palms, arum, yams, &c. In the Temperate Zones, a considerable portion of the food consists of animal substances, but the food-plants require cultivation to render them available for use. The native fruits and edible roots are of little value for nutriment, and are confined to limited areas, while the long dormant winters cut off the scanty supply. Hence, in this zone, where nature furnishes, so to speak, only the *germs* of food-plants, man is obliged constantly to supplement her work by forethought and intelligent labour. The animal food in the temperate latitudes of the Old World has, for ages, been chiefly derived from domesticated animals, while the Indian of the New World seems to have from time immemorial subsisted on fish and the produce of the chase. In the Frigid Zone, food-plants are almost entirely wanting, and man lives almost exclusively on the inhabitants of the sea. Of the innumerable species of plants in the vegetable kingdom, food-plants have by far the widest geographical range, as they extend from the equator to the extreme limits of the temperate zones. Many of them, as the cereals, are wholly dependent on the care and skill of man; while others, as the potato, beet, and cabbage, may indeed be found in their wild state, but so unlike the cultivated species as to be unfit for the table, and unrecognisable except by experienced botanists. Food-plants are divided into four classes—the cereals, edible roots and leaves, fruits, and juices obtained from the stems and roots of certain plants.

The Cereals.—Among food-plants these deserve the highest place. Yet they have never been found in the wild state except as mere grasses, and there is no trace of them in the records of geology any more than of man himself. Both appear on the scene contemporaneously, and in all ages each of them has been dependent on the other for continued existence. The cereals are all annuals, and grow only from seed; without man's assistance they cannot reproduce themselves, as they require cleared ground, open spaces, and well-tilled

fields for their cultivation. These essentials of grain-culture the savage never attains to, and hence, had man been originally a savage, there could be no cereals in the world. The celebrated botanist Van Meyen, virtually affirms this when he says that "the cereals must have preceded all civilisation." History fully corroborates this, as it shows that the human race makes its first appearance in the possession of high intellectual powers, and that, from the very first, man knew how to cultivate the cereals. The principal cereals are wheat, rice, maize, millet, oats, barley, and rye. Of these **Wheat** is the most valuable, and its geographical range is worthy of its importance. In Europe it will grow as far north as lat. 64° (on the west coast of Norway), and in N. America to 60° , while southwards it extends to the Tropic of Capricorn. It does not thrive in tropical countries, except in winter; but on the slopes of such lofty mountains as the Himalaya, it is cultivated on the northern side as high as 18,000 ft. above the sea. Wheat may be regarded as a sort of cosmopolite; but rice, maize, and millet are the cultivated grains of tropical countries; while barley, oats, and rye are confined to temperate regions. **Rice** delights in low swampy ground, where the wheat-plant languishes; in geographical range it rivals that of wheat, as it extends to 35° on either side of the equator, thus covering a full half of the land surface of the globe, while it forms the principal article of diet to one-third of the human race. It is of Asiatic origin, and is extensively cultivated in India, China, Japan, W. Indies, and the Southern States of America: in Europe it is confined to Greece, Lombardy, and Valencia in Spain. Carolina and Patna rice are the most esteemed kinds in the British market. **Maize**, or Indian corn, is a native of the New World, and was cultivated by the ancient Peruvians and Mexicans at the time of the Spanish conquest. They also fermented it, and obtained a kind of beer from it named *chicha*. It is now cultivated from Canada to Chili, as also in many countries of the Old World, but it was little used in Britain until the failure of the potato crop in 1846, when it was largely imported. **Millet**, or Durrah, is an important article of food in Egypt and tropical Africa, as well as Arabia and Turkey, and to a small extent in the United States as far north as lat. 42° . In Europe it is only grown south of lat. 45° . **Rye** grows further N. than any of the other cereals, and is largely cultivated in Russia, Germany, and Northern France, forming the principal staple of one-third of the population of the Continent. **Barley** will mature and ripen further north than any other grain, even as far as Hammerfest and the Faroe Isles: along with *Bere* (a coarser variety) it is extensively employed for malting and distilling. Though **Oats** will not grow so far north as barley, it thrives on poorer and thinner soil. It is extensively grown in Scotland, Norway, Russia, and Germany, and is distinguished above all the cereals for the quantity of gluten it contains, being nearly double that of wheat.

Edible Roots and Leaves.—Next in importance to the cereals as articles of human sustenance come the esculent roots and leaves, the principal of which are the following: the **potato**, forming the

highly-relished food of millions of people in European and other temperate latitudes; the **yam** and **sweet potato**, grown in intertropical countries, where the common Irish potato will not thrive; the **tapoca** of commerce, obtained from the root of the bitter cassava; and **arrowroot** from the roots or tubers of various tropical plants; while beet, onion, leek, garlic, radish, squash, carrot, and turnip, are cultivated for the most part in temperate countries, and the cucumber, melon, gourd, pumpkin, and calabash, in tropical regions. Important for yielding **edible leaves** are the cabbage, artichoke, cauliflower, broccoli, and spinach. Among **pulse** or leguminous plants may be mentioned peas, beans, and lentils.

Plants supplying Beverages.—Foremost among these is the **tea-plant**, a native of South-Eastern Asia, and largely cultivated in China and Assam; the **coffee-plant**, a native of Abyssinia, the seeds or berries of which are ground and infused; in the Eastern Archipelago an infusion of the coffee-leaf is a common beverage; **chicory-root**, extensively grown on the Continent, is used for adulterating coffee; **cacao**, the kernels of whose seeds supply the cocoa of commerce, which, when mixed with the seeds of the vanilla, produces **chocolate**; and the **maguëy** peculiar to Mexico, the sap of which is named "**pulque**" and drunk as a refreshing beverage both there and in Central America: it is like cider, and when sufficiently "hard" is intoxicating; the **yerba maté**, or Paraguay tea, which grows spontaneously in the forests of that country, and the use of which is universal in S. America.

Trees supplying staple Articles of Food.—Chief among these is the **artocarpus**, or bread-fruit tree; **banana**, or plantain (forty-four times more fruitful than the potato); **baobab**, or monkey-bread tree, the largest known tree; **bamboo**, every part of which is utilised; **cocoa-nut palm**,* **date palm**, and **sago palm**, the pith of which supplies the sago of commerce; **maple-tree** and **sugar-cane**, furnishing sugar (but sugar may also be obtained from many other plants containing starchy matter, as beet, &c.); the **olive**, so famous for its oil, which in southern Europe is largely used as an article of diet; and **carob**, or St John's Bread, common to all the countries washed by the Mediterranean.

Trees yielding choice Fruits.—The principal of these are the vine, fig, orange, pomegranate, guava, citron, lemon, apple, pear, peach, &c.

Narcotic Plants used as Luxuries.—Chief among these are **tobacco**, largely consumed in Europe and America, to which latter country it is indigenous; but according to the celebrated botanist Meyen, one species of this plant has been in use among the Chinese and other oriental nations from time immemorial; **opium**, extensively cultivated in India, Persia, and Turkey, and imported in vast quantities by the Chinese, &c.; **haschisch**, or Indian hemp, said to surpass the former in its intoxicating effects, is largely

* Palms are the most useful and beautiful of trees: they supply man with clothing, food, intoxicating beverages, shelter, and weapons. In the New World there are fully 60 varieties which are unknown in the Old.

employed by the Turks and Arabians. **Betel-nut** and **betel-pepper**, masticated generally by the natives of India and the South-Eastern Archipelago; **cocoa-leaf**, which has from a very remote period been the delight and support of the Indians of South America; **tonga**, a strong narcotic drink, prepared by the Indians of the Andes from the fruit of the red thorn-apple; the **hop** plant, reared extensively on the Continent and in America, but chiefly in England, which not only grows but consumes more than all other countries together. In short there is no nation, either ancient or modern, which has not had its own peculiar narcotic, and none so remote or savage which instinct has not led to successfully employ this form of indulgence.

Medicinal Plants.—The most celebrated of these are such as yield quinine, jalap, sarsaparilla, belladonna, gamboge, rhubarb, castor-oil, croton, aloe, liquorice, &c.

Ornamental and Sweet-scented Woods.—These are confined for the most part to the torrid zone, and embrace ebony, rosewood, mahogany, walnut, sandal-wood, thyme-wood, cedar, aloe, camphor-tree; besides which there are several fragrant resins, such as frankincense, myrrh, benzoin, and storax, with various odoriferous volatile oils, as the balsams of Peru and Tolu, and spikenard from the *jatamansi*.

Spices, Perfumes, Gums, &c.—The most important are cloves, nutmegs, allspice, pepper, ginger, capsicum, caraway, cinnamon, anise, mint, cumin, vanilla, tonga-beans, attar of roses, eau-de-Cologne; oils of bergamot, lavender, and other essences; gum-senegal, obtained from the mimosa, manna from the ash and from the *eucalyptus*, or Australian gum-tree, &c.

Dyes and other useful substances obtained from trees and plants are logwood, indigo, madder, red sandal-wood, Andaman red-wood, woad, laburnum, saffron, and annatto; pitch, tar, oil, wax, caoutchouc, turpentine, potash, resin, varnish, cork.

Trees supplying timber for shipbuilding, &c. Chief among these are teak, oak, live-oak, pine, kauri-pine of New Zealand (which furnishes spars for the Royal Navy), palm, cypress, fir, maple, yew, banyan, ash, elm, &c.

Remarkable Trees.—Amongst the most conspicuous of these is the cow-tree of S. America, which yields a juice very like milk in its properties; the tallow tree, the fatty matter of whose seed is used by the Chinese for making tallow candles.

Plants used for Textile Fabrics.—The most important of these is cotton, which will grow and mature at a moderate elevation anywhere between $37\frac{1}{2}^{\circ}$ N. and S. of the equator, thus embracing more than half the earth's surface. As yet, however, its cultivation has been chiefly confined to the southern tier of the U.S. of America (which produces the celebrated variety known as "Sea Island" cotton), Brazil, India, Egypt, the E. and W. Indies. Next to cotton comes flax or lint, which is a native of E. and S. Europe, but grows in most parts of the world. It requires, however, a cool temperature for the perfection of its fibre, so that its cultivation in tropical countries is chiefly for the sake of its seed, so valuable for the oil it

yields, while the refuse is used for making oilcake. Of the various textile fabrics, that of linen is the most ancient; it is made of the fibrous bark of the plant. The greater part of the flax imported into Britain comes from Russia, but the finest varieties are produced in Holland and Belgium, being delicate enough to yield thread for making lace. **New Zealand flax** is a tenacious fibre much used for cordage, and obtained from the sword-shaped leaves of the *Phormium tenax*. **Hemp** is the fibrous bark of another plant, extensively cultivated in continental Europe and many parts of America. It is used for the mnf. of ropes, cordage, sail-cloth, canvas, &c. The **Sun-hemp** of commerce is the fibre of a leguminous shrub, grown in the East Indies. **Manilla hemp** is the long fibre of the banana and plantain, while **coir** is the coarse woody fibre of the cocoa-nut husk, which is now extensively employed for the mnf. of matting. The beautiful **grass-cloth**, in the making of which the Chinese excel, is obtained from the fibre of a plant nearly allied to the common nettle. But, after flax and hemp, the most useful fibre is **jute**, imported in vast quantities by Dundee and other towns, where it is extensively employed in the mnf. of carpets, ornamental matting, sacking, and many other articles. It is nearly allied to the lime or linden tree, from the inner bark of which Archangel mats are made.

2. **Zoology** (from *zoon*, an animal) is that branch of biology which treats of the structure, habits, classification, and distribution of animals. Naturalists divide the Animal Kingdom into five subdivisions, according to their different types of organisation:—

(1.) The **Vertebrates** (from *verto*, I turn), having a jointed internal skeleton and separate cavities for the nervous cord and viscera, as in mammals, birds, reptiles, and fishes. (2.) The **Articulates** (from *artus*, a joint), which have no internal skeleton, but consist of a series of joints, and possess but one general cavity for the nervous cord and viscera, as in insects, crustaceans, and worms. (3.) The **Mollusks** (from *mollis*, soft), whose structure consists simply of a soft fleshy bag containing the stomach and viscera, as in the oyster, snail, cuttle-fish, &c. (4.) The **Radiates** (from *radius*, a ray), which have their structure arranged round a vertical axis, as in the star-fish, jelly-fish, and polyp. And (5.) The **Protozoans** (from *protos*, first, and *zoe*, life), which are mostly microscopic, and are the lowest and simplest forms of animal life. They consist of one or more cells, each one of which is capable of a separate and independent existence, as the rhizopods (from *rhiza*, a root, and *pous*, *podos*, a foot), so called from the root-like processes which they extend.

Number of Animals.—The barriers in the way of obtaining accurate statistics of the number of animal species are even greater than in the case of plants; and naturalists accordingly vary greatly in their estimates, not only of the probable number presently existing, but also of the known and described species. This statement need not excite surprise when we consider that many regions of the globe remain almost wholly unknown, while others have been but imper-

fetly explored ; that whilst the habitat of plants, when once discovered, can be visited and revisited by the botanist at pleasure, the great majority of animals are endowed with the powers of locomotion, and evade the pursuit of man ; that myriads of species are too minute to be seen by the naked eye, while others are too fleet or too formidable for being accurately observed ; that age and sex produce such changes in their appearance as often to render it doubtful whether or not the species are identical ; that many of them have their home in the depths of the ocean, or conceal themselves in the sand on the sea-shore ; while others seek shelter in the impenetrable recesses of the forest, or in inaccessible mountain-cliffs. M. Agassiz, the late eminent Swiss naturalist, estimated the total number of *known species*, including insects, at 250,000. But omitting from our reckoning the innumerable hosts of protozoans and insects, the following may be taken as a tolerable approximation to the existing number of species in the various subdivisions of the animal kingdom : Vertebrates, 20,000 ; Articulates, 5000 ; Mollusks, 20,000, and Radiates, 5000—total, 50,000 species. According to Johnston's 'Physical Atlas' the number of known mammals is 1967 ; birds, 8000 ; reptiles, 1600 ; and fishes, 8000—total, 19,567.

Distribution of Animals.—Though animals are endowed with the power of voluntary motion, and are therefore more capable than plants of transporting themselves from one region to another, various causes combine to limit the actual extension of individual species. Difference of climate, and the greater or less facility of procuring subsistence, are among the foremost of those causes ; while in regard to land-animals, arms of the sea and elevated mountain-chains present formidable barriers to migration. In numerous instances, however, we can trace the operation to no secondary cause, and little can be advanced beyond conjecture as to the way and manner in which a large proportion of the species came to be located in the precise regions where they are found, except by human agency and by floating icebergs (p. 72). In no other way can science satisfactorily solve the question how quadrupeds, for example, and other animals incapable of crossing arms of the sea, have found their way to islands situated in mid-ocean.

Restriction of certain Animals to particular Spots.—Owing to peculiarities of climate, soil, and food, some animals are confined to particular tracts : thus the reindeer and hamster are confined to the extreme north of Europe ; the wild boar and European lynx roam over the Continent ; the aurochs, the Caucasus and the Russian crown forests ; the chamois and ibex, the Alps ; and the marmot, the Alps and Pyrenees. The yak, Cashmere goat, Pamir sheep, burrhall, and musk-deer are common to Central Asia ; the royal tiger to Southern Asia ; and the gaval to the waters of the Ganges. The spotted and villose hyæna, quagga, and Cape buffalo are confined to South Africa ; the giraffe, eland, gazelle, gnu, springbok, civet, zebra, and wart-hog are found only in Africa ; while hippopotami frequent the African rivers. Common to Asia and Africa are the lion, elephant, striped hyæna, leopard, panther, rhinoceros, zebu, camel, ichneumon, and the common croco-

dile. The lemur is confined to Madagascar ; and, with one exception (the Barbary ape), monkeys to the torrid zone. Chameleons are distributed over the Old World (including Australia), but do not occur in America. The musk-ox inhabits the coldest parts of North America ; and the Canadian stag and buffalo or bison the temperate portions ; the grizzly bear is a native of the Rocky Mts. ; while the llama, alpaca, ocelot, prehensile-tailed monkeys, armadillo, and vampire-bat are peculiar to South America. Common to both the northern and southern continents of the New World are the puma, jaguar, racoon, skunk, peccary, tapir, sloth (chiefly S. American), porcupine, alligator, and rattlesnake. The elk or moose-deer and glutton live in the extreme north of Europe, Asia, and N. America ; and still further north roam the arctic fox and polar bear ; while to Oceania are peculiar the kangaroo, ornithorhynchus, &c. Among marine animals we find the common or "right" whale, seal, and walrus restricting themselves to the Arctic seas ; while the sperm-ceti whale and shark prefer the warm waters of the torrid zone. The pearl oyster is confined to the Indian seas ; the green turtle to the tropical seas of America ; and the coral insect to the waters of the torrid zone, where the mean temperature is never below 68° Fahr. The herring, cod, and salmon, however, mature best in temperate latitudes.

Birds.—The ostrich confines itself to Africa and Arabia, while mocking-birds and toucans are pre-eminently American ; indeed the condor (the largest bird of prey), the rhea, the hang-nests, and the humming-birds (so celebrated for the metallic lustre of their plumage, and some of which do not weigh 20 grains when alive) are exclusively South American. To Oceania belong the emeu, which nearly equals the ostrich in bulk, the anomalous apteryx of New Zealand, all bower-birds, the singular lyre-bird of Australia, and the laughing-jackass, whose song resembles a hysterical laugh ; while the birds of paradise, which take the first rank among the feathered glories of creation, are natives of New Guinea and the adjoining islands. Parrots, weaver and sun birds are denizens of the torrid zone ; while hornbills and hoopoes are distributed over many parts of the Old World.

The Geographical Range of the Domestic Animals.—Most of our domestic animals, such as the cow, horse, ass, sheep, and hog, are found wherever the grains and grasses grow ; the elephant is nearly confined to the equatorial regions of the Old World ; the camel and dromedary to the dry countries and sandy plains of the N. temperate zone ; the llama to the Andes of Chili and Peru ; the reindeer to the Arctic regions ; the yak to the mountains of Tibet ; while the dog is the faithful companion of man in every habitable region of the earth. The anatomical structure of the camel adapts him to desert and sandy countries, where the supply of wood and water is so scanty that other beasts of burden cannot traverse them. It is a curious fact that in the New World, where there are no such deserts, no camels are to be found. The llama is the camel of the American continent, and the only beast of burden employed by the natives at the time of its discovery. It is peculiarly fitted to climb the snowy heights of the

Andes, where the camel would be of no use. Its habitat in its wild state is close to the snow-line, where the atmospheric pressure is not more than 8 or 10 lb. on the square inch. The domestic animals of Europe, unless possibly the sheep, have been introduced from central and southern Asia.

Animal life in the different Continents.—Of the seven orders of land-animals, two (the *Pouched* and *Toothless*) are entirely absent in **Europe**, while other two (the *Quadrumanæ* and *Pachydermata*) are each represented by a solitary species—viz., the Barbary ape, inhabiting the Rock of Gibraltar, and the wild boar, a denizen of central and southern Europe. The *Carnivora* or flesh-eating animals are well represented in this continent, while it (with the exception of tropical America) contains a greater number of birds than any other zoological kingdom. Its reptiles, however, are all of insignificant size as compared with the gigantic crocodiles, alligators, and boas of the other continents. All the seven orders of land-animals are found in **Asia**; it is the great home of the highest of them, though their species are less numerous than in Africa, while it furnishes a greater number of animals capable of domestication than any other continent. It contains one-third of all known quadrupeds, while birds and reptiles are very numerous, and insects of large size and brilliant tints abound. **Africa** is eminently rich in the variety and high development of its animals. More than one-fourth of the known *mammalia* are found in this continent, while no fewer than 399 species are peculiar to it. Its carnivora, including the lion, leopard, panther, and hyæna are highly ferocious and formidable to man, but the tiger is nowhere found. The hippopotamus and giraffe are found nowhere else; the elephant and rhinoceros differ from those of Asia; while gorillas and chimpanzees inhabit the forests of the west. The ostrich is the most remarkable of its birds, the crocodile of its reptiles, and the locust and tsetse-fly of its insects. The whole list of savage quadrupeds, so common in the Old World, are unknown in **America**, while its own carnivora are of inferior size and fearful of man; but while the great majority of the species differ from those of the eastern hemisphere, they frequently resemble them in form. Thus the puma, jaguar, ocelot, llama, condor, rhea, and alligator of the New World, represent the lion, tiger, leopard, camel, eagle, ostrich, and crocodile of the Old. The humming-bird, so remarkable for the beauty of its plumage, is confined to the New World; and the toucan and condor are natives of South America. The animals of **Australia** and all Oceania are the most peculiar in the world. Of the seven great orders, three, the *Quadrumanæ*, *Ruminantia*, and *Pachydermata* are wholly wanting, while the *Marsupialia* or pouched animals are nearly all confined to that continent. Its largest and most characteristic animal is the kangaroo; while the most anomalous is the ornithorhynchus or water-mole, which has the bill and feet of a duck, the body and fur of a mole, and the internal structure of a reptile, which lays eggs like a bird, and suckles its young like a mammal. The songsters and gallinaceous birds are almost entirely wanting; but parrots of every hue, birds of paradise, and the beauti-

ful lyre-bird are numerous. The apteryx still exists in New Zealand, but the dodo has become extinct.

Extinct Species of Animals.—Among these we may note the moa or *dinornis* (*deinos*, terrible; and *ornis*, a bird), of New Zealand, which was from 10 to 12 feet high; the *apyornis* of Madagascar, of equal height, and the eggs of which were $13\frac{1}{4}$ inches long; also the solitaire and dodo of the Mauritius and adjoining islands, which have not been seen for two centuries. The Siberian manatee, and the great-auk of the North Sea, are likewise supposed to be extinct. The American buffalo is now seldom seen east of the Missouri, while the aurochs of Europe is confined to the Caucasian Mountains, and to the Russian imperial forests.

The Relation between Plants and Animals.—Vegetation forms the indispensable link between animals and inorganic nature. Plants alone have the power of transmuting the dead earthy matter into forms which the animal can take up and live upon. The atmosphere is composed of certain gases, some of which the plants receive into their structure, while the animals consume the others. Water is also essential to the life of a plant, but the principal ingredients of its food are derived from the atmosphere—viz., carbonic acid, oxygen, and nitrogen, together with a little earthy matter derived from the soil, consisting mainly of compounds of potash, lime, and soda. When we burn a tree, we soon reduce it apparently to a small heap of ashes, the weight of which is trifling when compared with that of the tree. The part, however, which has disappeared has not been annihilated, it has simply been converted into gas. The gas can be collected in a vessel and weighed, when it will be found that the combined weight of the ashes and gas is precisely equal to the weight of the tree. This is an interesting fact; but there is another fully as interesting—the part that has disappeared in burning is almost exclusively the portion which the tree derived from the atmosphere, while the ashes represent mainly what it derived from the soil. The ashes, however, contain a little charcoal, which is nearly pure carbon. This carbon did not come immediately from the soil, but from the carbonic acid gas ever present in the atmosphere. The plant has the power of separating the carbon from the oxygen, and of converting the former into wood, while the latter is allowed to escape as refuse. Thus a portion of the atmosphere is daily decomposed by every living plant, one part being converted into vegetable tissue, and the other set at liberty to perform other important functions.

How the Equilibrium of the Atmosphere is maintained.—It is calculated that carbonic acid gas forms only $\frac{1}{1000}$ of the atmosphere, yet out of this reservoir the whole vegetable world is supplied with its principal aliment. The leaves are the organs mainly concerned in decomposing the carbonic acid into its constituent elements, carbon and oxygen—the one of which is employed in building up all the trees and plants of the world, while the other is needed for respiration, combustion, and vegetable decay. All animals require it for breathing, fires require it to feed their flames, and thus plants and animals supplement each other in the economy of nature. The plants, however,

that throw out oxygen, and the animals that take it in, are often far removed from each other: the animals of the northern hemisphere far outnumber those of the southern, and consequently require larger quantities of oxygen. Plants are asleep in winter, and therefore throw off oxygen, and the innumerable fires kept burning at that period of the year in the northern zones, are all, with many others that might be specified, causes of great inequality in the amount of carbon and oxygen existing at one time in any given locality; but it is the office of the winds to restore the equilibrium: they establish a circulation in the atmosphere; they carry off the excess of gases from places where they are not wanted, and deliver them over for use in localities where they are needed.

Chief Agents in effecting the Equilibrium.—**Insects** number more than 100,000 species, each of which contains numberless individuals. Their agency in the economy of nature has ever been of extreme importance, especially in bringing the crust of the earth into its present condition, and fitting it for its present inhabitants. In addition to this, however, the task has been assigned them of preserving the necessary equilibrium between plants and animals, so as to prevent either of them from obtaining an undue predominancy over the other. Most insects are *herbivorous*, and almost every plant has some peculiar insect quartered upon it. The common nettle, for instance, is said to be the home of no less than 40 different species. Some insects appear to be necessary to the continued existence of the plants they inhabit, by conveying from the male to the female plant the pollen which engenders fructification; while other insects are mere parasites, devouring the leaves and blossoms, and thus precipitating decay. Generally speaking, when plants of a certain species become excessive, the insects that prey on them are found to multiply still more rapidly, and thus the indefinite increase of such plants is checked. Other insects, again, are *carnivorous*, and when the herbivorous ones unduly multiply, the carnivorous species prey upon them and prevent them multiplying indefinitely. Thus, by preventing the vegetable kingdom from gaining too much and destroying the animal, insects play an important part in the wonderful mechanism of nature, while one section of them also forms a necessary check on the other. Comparatively few insects, however, have been utilised by man. The Spanish fly enriches his pharmacopœia, the silk-worm and honey-bee eke out his food and raiment, and the cochineal insect he employs as a dye.

The part assigned to the **feathered tribe**, in the machinery of nature, is far inferior to that of insects. Birds are great fertilisers of the soil, especially in new lands, and to them we are indebted for our valuable deposits of guano. They have also assisted in conveying the seeds of plants from one country to another, and certain islands, more especially coral islands, are indebted to birds for the first rudiments of their soil and for their flora. Birds, like insects, are divided into two main divisions—the *herbivorous* and *carnivorous*—and it seems to be the office of birds and beasts of prey, as well as of the carnivorous insects, by their great powers of destruction, to pre-

vent the undue increase of the quieter and less ravenous species that feed on vegetation. Thus the lion and tiger prey upon the ox and horse ; the eagle and condor on the deer and llama ; the harpy eagle on the sloth ; and the tiny spider on moths, bees, and beetles.

Life in the different Zones.—Owing to the stimulating rays of a vertical sun, vegetation attains its greatest development in the torrid zone ; and (as has been already explained) so dependent are plants and animals on each other, that wherever vegetable life is most varied and luxuriant, there animal life is also most exuberant in size, number, strength, and beauty. With the decreasing amount of light, heat, and moisture, a gradual declension takes place in the variety and perfection of the types as we proceed from the equator to the poles. In the **Torrid Zone**, vegetation is remarkable for the abundance of genera and species, the magnitude of individual forms, the vast extent of primeval forests, the numerous climbing and parasitical plants, the great development of foliage, and the number of large flowering trees. Ferns here rival the trees in size and beauty, aromatic shrubs and delicious fruits abound ; while reeds and grasses attain their greatest proportions, palms of every variety, bananas, banyans, rice, manioc, cotton, coffee, sugar-cane, ornamental and scented woods, spices, &c.—in short, the greatest variety and number of food-plants, and of those which contribute to the luxury of man—are natives of this zone. This is also the chosen home of the most powerful beasts of prey, as the lion, tiger, panther, &c. ; of apes and monkeys ; of the elephant, rhinoceros, and hippopotamus : here reptiles and insects of all sizes and hues abound, and here the ornithology exceeds in strength and splendour that of any other zone—that of South America alone comprising 624 species, or one-twelfth of all known birds. The shark is also a native of this zone, and the sperm whale is confined to the tropical areas of the Pacific. The **Warm Temperate Zone**.—Here the choicest varieties of the vine and other delicate fruits abound. The trees—such as the live-oak, myrtle, laurel, mulberry, olive, &c., are all evergreens, but continue dormant through the winter. Antelopes and camels are the most characteristic animals of this zone. In the **Temperate Zone**, where the sun's rays are more oblique, the trees are deciduous and the forests less dense (though, as in North America, occupying vast areas and containing stately trees), while the foliage and flora are less luxuriant. Hemp, flax, and tobacco are natives of this zone ; but the food-plants, though numerous, require cultivation to make them valuable to man. The ruminants—such as the ox, elk, stag, and deer—characterise this zone ; here, also, is the home of most of the domestic animals, and of those insects which contribute most directly to man's comfort. **Cold Temperate Zone**.—Here dark forests of coniferous trees, such as the fir and pine, abound, and here also the hardiest of the cereals (oats, barley, rye) are brought to perfection. The most conspicuous animals are the great moose and brown bear, together with the beaver, sable, ermine, mink, &c. Birds and reptiles are monotonous and sombre in colour, and many of the former migrate in winter to warmer climes. **Arctic Zone**.—The vegetation

here consists of but a few stunted varieties of willow, birch, and pine in the lower latitudes, and mosses and lichens in the higher. The reindeer, musk-ox, polar bear, elk, and smaller furry animals are innumerable, but reptile life is unknown. The Arctic seas are the headquarters of the most gigantic *cetacea*, such as the "right" whale, walrus, seal, &c.

3. Ethnography.—Man, from the perfection and beauty of his bodily organisation, and from the order of time in which he was called into existence, occupies the apex of the vast pyramid of animal life. Of all animals he only walks erect, his eye reflecting earth and sky, and his look glancing freely over that world in the midst of which he lives and reigns. Over his whole form there is an air of more than material beauty, the reflection of a soul infinitely rich in thought and emotion; while by possessing an immortal spirit he is raised immeasurably above material things, and separated, as by an impassable gulf, from all other animals. In common with these, he is, to some extent, subject to the influence of external circumstances, though in a less degree than any other species. His superior intelligence, and the pliancy of his constitution, fit him to become the denizen of all countries, and all varieties of climate, from the scorching heat of the tropics to the rigorous cold of Arctic latitudes. His geographical distribution, accordingly, differs from that of all other organic beings, and man is the only true cosmopolite. Of the vast number of countries brought to the knowledge of Europeans by modern discovery, very few were found uninhabited; the principal exceptions being Iceland, Spitzbergen, and Novaia Zemlia; Madeira, the Azores, and St Helena; the Falkland Isles, the Galapagos, some minor groups in Polynesia, and the inhospitable regions around the South Pole.

Unity of the Species.—Man is of only one species, and the so-called *races* of men are mere varieties of the same species, differing less from each other than do the varieties of many other animals; as, for example, the dog, the horse, the sheep, and the domestic fowl. Science and Revelation alike proclaim this fundamental truth: the one, by establishing an identity of anatomical structure between the races, the same period of gestation, the same instincts, longevity, and diseases, the same mental and moral character, and the fertility of offspring arising from intermixture of blood: and the other, by declaring that in one man was the germ of the whole human family; that the myriads of men that now people the earth, after the lapse of a hundred and fifty generations, are all *brethren*, united together by the closest ties; and that the universal depravity and death which have their root in the common ancestor of all, are more than counterbalanced by the obedience and sufferings of his glorious Descendant, whom every human being can claim as his near kinsman.

Origin of Races.—Yet in all ages and countries the individuals of the human family have presented numberless diversities of appearance; and though all are specifically identical, every member of the family exhibits his own proper *individuality*—that is to say, certain characteristics of physical organisation and of mental disposition that distinguish him from every other individual of the species. For Man is a complex being, and embraces within him a world of diverse elements, that rival, in their various riches, the world of external nature. These elements are capable of combination in infinitely varied proportions. In one the soul predominates, in another the body; here the nervous system bears rule, there the arterial; here the affections, there the understanding. The laws and the causes, however, that determine these combinations, are to us a secret; for individuality is a mystery of life, the stamp of the Creator. This much, however, seems certain,—viz., that while the distinctive character of the soul never fails to manifest itself very perceptibly in the entire physical organisation—especially in the form of the head and in the physiognomy—the influence of external nature, of the family, of society, of habit, and of education; is but of secondary importance, tending merely to modify the original individuality. Yet, by a constant and unvarying repetition, carried on through a long series of generations, even the latter influences may produce very important effects; though never to the extent of eradicating the outlines of this individuality, which, notwithstanding the constant intermingling of blood by marriage, perpetuates itself for ages from father to son, in the same family, every member of which resembles, both in temperament and physical organisation, some one or other of his ancestors or blood relations. Accordingly we find that, from the earliest dawn of history, mankind has been divided into races, and organised into nations; and it is one of the first lessons of Revelation that with this division human design and human choice had nothing whatever to do,—that it was exclusively the work of the Creator; with nature to aid in its accomplishment,—and that these races and nations were distributed over the earth's surface according to a definite plan, in which each had assigned to it its proper part in the progress of events. Each region, moreover, strengthened and modified the character of the race that was conducted into it; and thus national characteristics, which become more and more marked as generations succeeded each other, attained at length such a degree of fixedness and inflexibility as has enabled them to traverse the ages of history, and encounter the most opposite influences, without undergoing any radical change.

Dispersion of Nations.—The precise locality in which the dispersion of nations originated, and the precise date at which it took place, are not easily determined; but there can be no doubt that we must look for the former to Western Asia, and for the latter to the fifth generation after the Deluge. Asiatic Turkey, situated in the centre of the Old World, and midway between its four great oceans, has been twice the cradle of mankind, and still remains the region in which the human form attains its highest perfection. Here Noah

with his family, the sole survivor of that great catastrophe which swept away the inhabitants of the antediluvian world, took up his destined abode; and here his three sons—Shem, Ham, and Japheth—like branches cut from the same tree, took root and flourished, containing within themselves the germs of the three great races, and of all the minor varieties, that subsequently peopled the earth. The distinctive characteristics of the ancestors were indelibly impressed on their respective descendants: thus spiritual and religious tendencies predominated in the offspring of Shem; the sensual and corporeal in those of Ham; while the nations that sprang from Japheth have been no less remarkable for their fuller development of all the powers of the mind. Accordingly, when the set time for the great dispersion arrived (B.C. 2550, according to W. Osburn), Ham and Japheth wandered far from the ancestral home, in quest of abodes congenial to their respective natures; while Shem retained possession of the paternal altars, became the custodian of the one true faith, and the ancestor of that promised Seed of the Woman in whom all nations of the earth shall yet be blessed. Regarding this distribution from another point of view, we observe a curious and remarkable anomaly; for while all the other types of animals, as also of plants, go on decreasing in perfection from the equator to the poles, man presents to our view his most perfect type at the centre of the north temperate zone, in the mountain regions of Iran and Armenia; whereas, departing from that region, whether to the north, south, or east, the types gradually lose their symmetry, till, at the remote extremities of the continents, we find the most deformed and degenerate races.

Number and Characteristics of Races.—Modern ethnography classifies the numerous nations that people the globe into three primary races—viz., the Caucasian, or white and bearded race; the Mongolian, or tawny and beardless race; and the Negro, or black-skinned and woolly-haired race. These are confined to the Old World, and correspond, with certain limitations, to its three continental divisions: the Caucasians occupying nearly all Europe, south-western Asia, and the north of Africa, and extending from Iceland and the Atlantic to the Ganges and Brahmaputra, and from the Arctic Circle to the Tropic of Capricorn; the Mongolians peopling all the rest of Asia, together with certain isolated localities in central and northern Europe; and the Negro race, the whole of continental Africa south of the Tropic of Cancer. In addition to these there are several minor varieties, inhabiting Oceania and the New World, and probably originating in the intermixtures and modifications of the three primary races: as the Malaysians in Malaysia and Madagascar; the Papuans in New Guinea and New Hebrides; the Maoris or Australians in Australasia; and the Americans, or aboriginal inhabitants of North and South America. The more prominent characteristics of the principal races are the following:—

White or Caucasian Race.—The skull symmetrical, of great capacity, and well poised; face oval, and features moderately prominent; nose narrow; eyes large, but mouth small, and the lips gracefully curved; skin varies in colour with the climate from white, with ruddy cheeks,

in the European, to light brown in the Hindu and Egyptian. Stature tall and graceful, muscular strength great, intellect highly developed; languages polysyllabic, copious, and highly inflexional. This type is divided into two branches—the Aryan, Indo-European, or Japhetic branch, and the Syro-Arabian or Semitic branch. (See Author's "Manual," pp. 86, 358.)

Mongolian Race.—Head round, and narrow at the top; face flat, with prominent cheek-bones, low forehead, and obliquely set eyes; stature short, and skin yellow. Intellect moderately developed, but shrewd, sagacious, crafty, and insincere. Languages inartificial, limited in range of literature, and divided into two principal families—the monosyllabic, which is destitute of inflexions, and the Turanian or Finno-Tatarian, which is slightly inflexional and phonetic. ("Manual," p. 356.)

Negro or Ethiopian Race.—Head narrow and elongated backwards; forehead convex, retreating, and narrow; nose broad and flat; cheek-bones prominent; both jaws much elongated, with the front teeth of the upper turned obliquely forward; lips very thick; hair crisp and woolly; stature of average height. Intellect without depth or comprehensiveness, but acute and perceptive. Languages agglutinate, slightly inflexional, but one stage removed from the simplest monosyllabic, and without a written literature.

IX.—GEOLOGY.

Geology is the science which treats of the earth's structure and system of development, including its progress in physical conditions, as its gradual cooling (see p. 21), the formation of minerals and rocks on its surface (*Lithology*), and its ancient life history (*Palæontology*). We have specially to consider three things—minerals, rocks, and fossils.

1. **Minerals.**—The sixty-five constituent elements forming the earth's crust are, in general, characterised by a strong affinity for each other, disposing them to form compound bodies, each of which possesses properties widely different from those of its constituents. These compounds are termed *minerals*, and the science which treats of their forms, composition, and other properties, is called Mineralogy.

Number of Minerals.—The number of mineral species at present recognised by science somewhat exceeds five hundred, many of them having, in addition, a great number of varieties. They are classified by mineralogists into seven orders and thirty-seven families. These orders, with their respective families, are as follows: *Oxidised stones*, comprising 12 families—quartz, felspar, scapolite, haloid stones, leucite, zeolites, mica, hornblende, clays, garnet, gems, and metallic stones. 2. *Saline stones*, 5 families—calc-spar, fluor-spar, heavy-spar, gypsum, rock-salt. 3. *Saline ores*, 3 families—sparry iron ores, copper salts, lead salts. 4. *Oxidised stones*, 5 families—iron ores, tin-stone, manganese ores, red copper ores, white antimony ores. 5. *Native Metals*, forming only one family. 6. *Sulphuretted metals*, 6 families—iron pyrites, galena, grey

antimony ore, grey copper ore, blende, ruby blende. 7. *Inflammables*, 5 families—sulphur, diamond, coal, mineral resins, inflammable salts.

Forms of Minerals.—Mineral substances occur in nature in two distinct modes of aggregation—amorphous and crystallised. When the particles of the mineral are merely collected together, without exhibiting any regularity of structure, it is called *amorphous*; but should the mineral possess a definite chemical composition, together with a regular symmetrical external form, it is said to be *crystallised*. Generally speaking, every mineral substance, whether simple or compound, is found in nature with a form peculiar to itself, which readily distinguishes it from all other minerals. Many of them, moreover, exist in various allied forms, and hence the number of natural crystals is enormous. Mineralogists, however, have succeeded in arranging them all under *six systems* of crystallisation, to each of which belongs a number of forms having some properties in common. In every crystal there are found three *axes*, which intersect at its centre and pass through from side to side, and the entire classification depends on the relative lengths and position of these axes. 1. The first system is named the *Regular or Tesseral System* (from *tessera*, a cube), and is characterised by three equal axes intersecting each other at right angles. It includes the cube, the regular octohedron, the rhombic dodecahedron, and the regular tetrahedron. Some of the best-known minerals that assume one or other of these forms are common salt, alun, fluor-spar, iron pyrites, grey copper ore, and boracite. 2. The *Quadratic or Tetragonal System*, with three axes at right angles, but one shorter or longer than the other two. Eight principal forms, with numerous varieties, belong to this system, among which are included the first and second right square prisms, and the first and second right square octohedra; examples—zircon, stannic oxide, and yellow prussiate of potash. 3. The *Hexagonal or Rhombohedral System*, with four axes, three of which are equal, intersecting each other in one plane at 60° , and one principal axis at right angles to them. It embraces the regular six-sided prism, the regular six-sided pyramid, and the rhombohedron. Rock-crystal, calc-spar, beryl, corundum, graphite, and many other minerals, assume forms belonging to this system. 4. The *Rhombic System*, characterised by three axes, all unequal, but at right angles to each other: its principal forms are the right octohedron with rhombic base, and the right rhombic prism. This system comprises only a few varieties of form essentially distinct, but embraces nitre, native sulphur, topaz, and arragonite. 5. The *Monoclinic or Monoclinohedric System*, having three unequal axes, two of which intersect each other at an oblique angle, and are cut by the third at right angles. The forms peculiar to this system—among which is the oblique rhombic octohedron—approach very near to those of the rhombic, but the inclination of the axes enables us readily to distinguish them. As examples of the numerous minerals assuming one or other of its forms may be mentioned sulphur deposited from fusion, sodium carbonate, and borax. 6. The *Triclinic or Triclinohedric*, with three axes, all unequal and all oblique. This is the least regular of all the systems, and departs the most widely from symmetry of form. The doubly-oblique octohedron and the doubly-oblique prism are the leading forms; examples—copper sulphate, boracic acid, and albite.

2. Rocks.—Minerals aggregated together, so as to form large masses, are technically called *rocks*. These rocks, according to their structure, are of two kinds; either they consist of minute

particles of one and the same mineral, or of two, three, or more different minerals aggregated together. The former are called *simple*, the latter *mixed rocks*. Thus, for instance, *marble*, consisting of nothing but grains of carbonate of lime, is a simple rock; while *granite*, on the contrary, which is made up of small crystals of quartz, felspar, and mica, is a mixed rock. The component parts of a rock are either crystallised together, or they are united by a non-crystalline cement, as in conglomerates, pudding-stone, breccia, &c. In many rocks the cohesion is very great, as for instance in greenstone; while in others it is but slight, as in sandstone, gravel, coal, &c. As compared with the vast variety of minerals, the number of distinct rocks is exceedingly small. They are also pretty uniformly distributed over the globe, while none of them is peculiar to any particular country. Thus, while the plants and animals of tropical regions differ exceedingly from those of the frigid zone, the materials which form the mountain-ranges, as well as the pebbles along the sea-shore, are everywhere the same. Notwithstanding, however, this general uniformity, there is considerable local variety, depending on the geological character of the place. Thus a traveller setting out from London, either to Berwick or Land's End, will find the character of the rocks continually varying as he proceeds from county to county; and before he arrives at his destination, he will have passed in review almost every variety of rock in the geological scale. In like manner, when a considerable *section* of the earth's crust is exposed to view—as in sea-cliffs, quarries, mines, and railway cuttings—a great variety of rocks is discernible; but they may be all reduced to two principal kinds. They are either arranged in beds or layers, and hence known as *stratified rocks*; or they are found in shapeless, indeterminate masses, destitute of any such arrangement, and therefore called *unstratified* or *igneous* rocks.

Unstratified Rocks.—These rocks have everywhere the appearance of having existed at a former period in a molten state; and the numerous varieties of beautiful crystals found associated with them are a striking testimony of their having cooled down with great slowness and regularity. Generally speaking, they occupy a lower position in the crust than the aqueous; though they are often seen overlying the latter, or separating the strata of which they consist, or forcing their way through those strata in veins, rents, and fissures. They are usually divided into three principal kinds—*granitic*, *trappean*, and *volcanic*. The first of these is reckoned the oldest, as it is generally found underlying or associated with the oldest series of the stratified rocks; the second is considered more recent in its origin, because occurring for the most part among the secondary and tertiary formations; and the third, as the newest of all, being generally found associated with those modern formations which have been deposited since the tertiary era. The following are the principal rocks belonging to these three varieties, beginning with the lowest:—

Granitic: Common granite (consisting of small regular crystals of quartz, felspar, and mica), porphyry or porphyritic granite, syenite, protogine, pegmatite, hornblende rock, primitive greenstone, serpentine, felspathic rock, &c.

Trappean: Basalt, greenstone or dolerite, clinkstone, compact felspar, hornstone, pitchstone, claystone, amygdaloid, trap-tuff, &c.

Volcanic: Lava, trachyte, obsidian, pumice, pearlstone, tufa, scorïæ, palagonite, sulphur, pozzuolana, &c.

Igneous rocks are very widely distributed, and play a most important part in the physical aspect of many countries. The mightiest mountain-ranges on the earth's surface are mainly formed of the granitic series, as the Alps, Pyrenees, Ural, and Grampian Mountains in Europe; the Himalayas in Asia; the Abyssinian Mountains in Africa; and the Andes in South America. The prevailing scenery is dreary and monotonous, and the soil barren and inhospitable. But the economic uses of granitic rocks are numerous and varied. They form exceedingly durable building-stones, admirably fitted for bridges, lighthouses, docks, fortresses, and as road and street materials. When polished they are generally highly ornamental, and are therefore employed for obelisks, tombstones, and pillars. The industrial products of the trap-rocks are also numerous, though not of equal importance. Some basalts and greenstones make good building-stone, but the difficulty of dressing them into the required shape prevents their extensive use. Nearly all the sulphur of commerce is derived from volcanic regions; pumice has long been used as a polishing or rubbing stone; while many of the lavas yield precious stones, and others are metalliferous.

Stratified or Sedimentary Rocks.—These are divided into two great series—the Crystalline or Non-fossiliferous, and the Fossiliferous. The former,—also called Metamorphic rocks,—are usually found immediately above the granitic, separating them from the fossiliferous strata above, and embrace the following members—viz., gneiss, mica-slate, clay-slate, hornblende-schist, talc-schist, actynolite-schist, chlorite-schist, quartz-rock, and primary limestone. Although gneiss usually occupies the lowest place in the series, these rocks do not follow any invariable order, and not unfrequently one or more of them is wanting. The materials of these strata appear to have been originally deposited by water in the form of sediment, and to have been subsequently so altered by subterranean heat as to assume their present crystalline texture. At the time of their original formation they were probably replete with organic remains, similar to the fossiliferous systems above them; but the intense heat proceeding from the underlying granite has destroyed every vestige of organic matter. In regions where the Metamorphic rocks lie near the surface, the scenery is usually bold, rugged, and picturesque, and the soil unproductive; but slate, marble, and building-stone are obtained in them, and not unfrequently tin, copper, lead, silver, and gold.

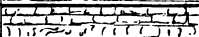
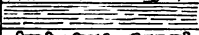
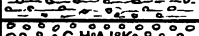
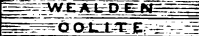
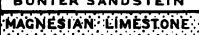
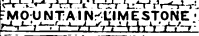
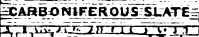
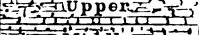
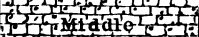
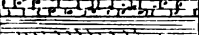
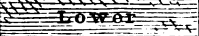
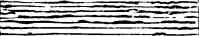
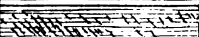
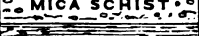
3. Palæontology.—By carefully studying the fossiliferous strata above mentioned, we obtain most important information regarding the earliest stages of the earth's existence—information, in fact, nowhere else to be found. We learn, for example, that our world had arrived at a hoary antiquity before the creation of man; that it was not then a barren, untenanted wilderness, but the happy home of innumerable races of living creatures, which, once and again, were swept away by great

natural catastrophes, and replaced by other orders of plants and animals, higher in the scale of being than their predecessors, and more nearly approximating the many races, animal and vegetable, which are now placed under man's dominion. This knowledge is partly derived from the lithological character and immense depth of these strata, each of which, in its turn, must have been slowly deposited by the waters of seas, lakes, or rivers; but principally from the countless petrified remains of the animals and plants that had their abode in the waters or on the land, at the period of their formation. The branch of geology which treats of these organic remains is termed Palæontology (from *palaïos*, ancient, *onta*, beings, and *logos*, a description), signifying a description of ancient organisms. The long-continued study of the fossiliferous strata of many countries has enabled geologists to arrange the entire series into ten distinct and well-defined *systems*, each of which differs essentially from all the others, both as regards its lithological constituents and its petrified organisms. These ten systems are further grouped into three great *series*, or *periods*—viz., the PALÆOZOIC, or most ancient; the MESOZOIC, or secondary; and the CAINOZOIC, or most recent. The accompanying diagram indicates at a glance the precise place in the geological scale where each higher order of organised existence made its first appearance.

1. The Laurentian System.—This, the most ancient of all known fossiliferous deposits, derives its name from the river St Lawrence, in the basin of which it occupies an immense area. Sir W. Logan, of the Canadian Geological Survey, regards these rocks as the most ancient on the American continent, and as the equivalents of the oldest gneiss of Scotland and Scandinavia. In the geological scale they occupy a lower position than the Cambrian rocks of North Wales, and consist of highly crystalline gneissoid and hornblende schists, which, in some localities, attain a thickness of 30,000 feet. Principal Dawson, the eminent Canadian geologist, has recently (1868) detected in the lower formation of these rocks what may justly be regarded as the earliest indication of animal life on our globe. This consists of a foraminifer, named by him *Eozoon Canadense*, a humble ZOOPHYTE, and one of the very lowest types of the animal kingdom. This zoophyte has since been detected in Bohemia, in strata underlying the Silurian rocks.

2. The Cambrian System.—(From *Cambria*, the ancient name of Wales), a term employed by Professor Sedgwick to designate the lowest fossiliferous rocks in North Wales. They consist mainly of slaty, gritty, and silicious beds of immense thickness (from 20,000 to 30,000 feet), which are regarded as the geological equivalents of the fossiliferous schists of Wicklow, the lower greywacke of Dumfries, the Northern Highlands of Scotland, the alum-schists of Sweden, and the Huronian sandstone of America. A deeper interest attaches to the Cambrian and Laurentian systems than to any other in the geological scale, on account of their containing the petrified remains of the earliest living inhabitants of our planet. These consist of FUCOIDS, a humble genus of marine plants; of Zoophytes (*Oldhamia*) and Graptolites, the lowest forms of

SUCCESSION OF LIFE ON THE GLOBE.

POST-TERTIARY.	PREHISTORIC.		MAN.
	PLEISTOCENE		HUMAN WEAPONS. EXISTING MAMMALS.
TERTIARY.	PLIOCENE.		MAMMALS OF EVERY ORDER.
	MIOCENE.		
	EOCENE.		
SECONDARY.	CRETACEOUS		CTENOID & CYCLOID FISHES. EXOGENOUS TREES.
	JURASSIC.		PLACENTAL MAMMALS.
			SCREW-PINES, YEWs, &c.
			GIGANTIC REPTILES.
	TRIAS.		MARSUPIAL MAMMALS.
			CHELONIAN REPTILES.
			BIRDS.
	PERMIAN.		SAURIAN REPTILES.
	CARBONIFEROUS.		BATRACHIAN REPTILES. SAUROID FISHES. CONIFEROUS TREES. HUGE PALMS, TREE FERNS.
			
			
PALEOZOIC.	DEVONIAN.		PLACOID & GANOID FISHES INSECTS.
			
			
	SILURIAN.		LAND-PLANTS.
			PLACOID FISHES. LAND-PLANTS.
			TRILOBITES. MOLLUSCS.
			ECHINODERMATA.
	CAMBRIAN.		TRILOBITES, MOLLUSCS. MARINE PLANTS.
	LAURENTIAN		ZOOPHYTE. (Foraminifer.)
HYPOTONIC.	METAMORPHIC.		
PLUTONIC.	IGNEOUS.		

animal life; of brachyopodous MOLLUSCS (lingula and terebratula); and of Trilobites (olenus and paradoxides), a remarkable family of CRUSTACEANS peculiar to the Palæozoic period.

3. **The Silurian System**, so called on account of its huge development in south-eastern Wales, a locality once inhabited by the *Silures*, an ancient British tribe. Here it amounts to about 8000 feet in thickness, forming several distinct formations, which differ essentially in the character of their organic remains. The prodigious development of fossils has no parallel in the underlying formations. In the British Isles alone, in 1867, the Silurian strata contained 1194 recognised species, only 8 of which were plants. In a small tract around Prague in Bohemia, the indefatigable M. Barrande enumerates no fewer than 2735 species; while Dr Bigsby, in his '*Thesaurus Siluricus*,' a work of immense industry and research, enumerates 7553 well-defined species as belonging to all countries. By inspecting this great work it will be perceived that in the Silurian age of the world's history all the classes of the invertebrate division of the animal kingdom are well represented, but that Molluscs, Echinodermata, and especially Trilobites, existed in vast numbers. But what imparts the deepest interest to the Silurian system is that it affords the earliest evidence both of vertebrate animals and of land-plants. These occur in the uppermost strata of the Ludlow rocks, and immediately underlying the lowest beds of the Devonian system. The vertebrata consist of FISHES of the genus *Pteraspis*. They are few in number, small in size, and of the lowest order. They are all cartilaginous fishes, like the skate and dog-fish—for fishes with ossified vertebrae are not found till we arrive at the Devonian strata. The land-plants are also of the humblest rank, belonging to the family *Lycopodiaceæ*, and allied to our present club-mosses. Fishes have also been found in the Lower Silurian formation. Silurian strata are extensively developed in many countries, especially in Wales, the south of Scotland, Bohemia, Russia, Scandinavia, North and South America, and Australia. The veins that traverse the system are usually metalliferous, yielding mercury, copper, lead, silver, and gold. It is mainly from rocks belonging to this system that the prodigious quantities of gold recently brought to light in Australia, California, the Ural Mountains, and other localities, have been obtained. They also yield flagstones, roofing-slates, and limestone for mortar and manure. In Silurian districts, the scenery is usually varied and picturesque, less abrupt and bold than in metamorphic regions, yet more diversified by hill and dale than Secondary strata; but in Russia, south of the G. of Finland, they form wide level plains, or low plateaux. The late Sir Roderick Impey Murchison, the prince of British geologists, has been the chief investigator of this system.

4. **The Devonian or Old Red Sandstone System** overlies the Silurian, separating it from the Carboniferous system. But Hugh Miller, its most illustrious explorer, divides it into three formations—Lower, Middle, and Upper. It is largely developed in Scotland, South Wales, Devonshire, Belgium, Russia, and North America, where it usually consists of a succession of sandstones, alternating with layers of sandy shale and beds of concretionary limestones. The flora of the system consists partly of marine, but chiefly of land plants, of a greatly higher order than those found in the uppermost beds of the Silurian. Some twenty years ago, the author of this work discovered several huge calamites in the lowermost strata of the Old Red Sandstone of Aberdeenshire, previously regarded as unfossiliferous. Cone-bearing trees—plants as high in the scale of nature as the pines and cedars of the present day—were found by

Miller, long previously, in the same formation at Cromarty; while Dr Dawson has recently discovered no fewer than 82 species of land-plants in the Devonian strata of Nova Scotia. To such an extent, indeed, did land-plants abound in the Devonian age, that in some localities thin seams of bituminous coal have been discovered in it. Perhaps the most beautiful species of the Devonian flora was the *Adiantites Hibernicus*, a tree-fern, obtained from the yellow sandstone series of Ireland and Roxburghshire. The fauna of the system displays an equal development; for though the Trilobites, which so pre-eminently characterised the Silurian system, have passed their meridian, other crustaceans of a still higher order appear in their room. The most remarkable of these is the *Pterygotus Anglicus*, a gigantic lobster-like crustacean, from 4 to 6 feet long, found in the Devonian rocks of Hereford, Forfar, and Ulster in Caithness. Here fishes exist in vast numbers, and of two distinct orders—Placoids and Ganoids—the latter with osseous vertebrae and dermal skeletons. Among the most characteristic forms are *Onchus*, *Cephalaspis*, *Coccosteus*, *Asterolepis*, *Dipterus*, and *Holoptychius*. INSECTS make their first appearance in the Devonian rocks of N. America, but the reptilian remains of Elgin, formerly supposed to belong to this system, are now assigned to the Trias. In 1858, the total number of fossil species belonging to British Devonian rocks amounted to only 300; but the total number of species known in 1867 was 532. The minerals of the system are mainly building-stone of inferior colour and durability, paving-slabs of excellent quality, which are extensively exported from Caithness and Forfarshire; while to the trap-rocks of the system the lapidary is indebted for his agates, jaspers, and Scotch pebbles. The scenery is generally flat and tame, though occasionally highly diversified; and the soil, owing to its porousness, is usually well adapted for agriculture.

5. **The Carboniferous System**, so called from the profusion of vegetable matter (*carbon*) which it contains, consists in like manner of three formations—the Lower Coal-Measures, the Mountain Limestone, and the Upper Carboniferous, or true Coal-Measures. Not unfrequently one of the members is wanting, and sometimes beds of one formation alternate with those of another. In some parts of Scotland the Lower Coal-Measures yield great quantities of serviceable coal; while in Ireland, where the formation is so enormously developed, little coal is found. Wherever this formation exists, it presents indications of having been deposited in fresh water, in estuaries, or in inland seas. The Mountain Limestone, again, is essentially a marine deposit, and, by the peculiar character of its fossils, forms the most easily recognised formation in the geological scale. The Upper Coal-Measures, like the Lower, are mainly of lacustrine origin, and consist of alternations of sandstone, coal, shale, ironstone, clay, and impure limestone. The minerals of this formation, especially its coal and iron, form an inexhaustible source of wealth to those countries where they most extensively prevail. In Britain, especially, they mightily contribute to our power and eminence amongst neighbouring nations. The flora of the system is the most abundant and gigantic that ever appeared on the earth's surface—consisting of coniferous trees of immense size, huge palms, tree-ferns, lepidodendra, calamites, sigillariae, equisetæ, club-mosses, and other allied forms. Wherever any of the carboniferous formations occurs, these crowd every bed of shale, and form the materials of which every seam of coal consists. Considering, then, that the Coal-Measures exist in numerous lands and in all latitudes, and that these plants all belong to a tropical vegetation,

the obvious inference is, that during the deposition of the carboniferous strata a hot moist climate prevailed over the entire surface of the globe (see pp. 30, 31). The fauna is less peculiar than the flora, but it equally marks distinct progress in organic development. Here saurid fishes, and REPTILES of the Batrachian or lowest order, appear for the first time. The number of plants hitherto discovered in the whole system amounts fully to 1700, of which British strata furnished 1100 species. Carboniferous strata cover large portions of the British Isles. In England they extend from Derby to Berwick, but the Upper Coal-Measures are chiefly confined to south Wales and the valley of the Tyne. In Scotland they form a broad belt across the country from the coast of Ayrshire to Fife. Ireland is not rich in coal, all her coal-fields being situated in the carboniferous limestone, which covers the central plain. On the Continent the principal localities are the north of France, Belgium, Germany, Prussia, Austria, and the south of Russia. In extra-European countries the main localities are, Hindostan, the coasts of Chili and Peru, the Isthmus of Panamá, Nova Scotia, and especially the United States of America, where the Coal-Measures occupy an area of 600,000 square miles. The economic importance of this system cannot be overrated. It furnishes nearly all the coal consumed in every civilised country. In the British Isles alone about 130,000,000 tons of this valuable mineral are dug annually. Almost equally important is the iron, which is usually associated with the coal. Other products of the system are, petroleum, asphalt, naphtha, paraffine-oil, copperas, ochre, alum; the ores of lead, zinc, and antimony; marble, limestone, and building-stone of the finest quality. The scenery, with the exception of some limestone districts, is generally tame and unpicturesque, while the soil is often cold and only moderately fertile.

6. **The Permian System**, so named from its enormous development in the government of Perm, in Russia, forms the uppermost member of the great Palæozoic series of rocks. It consists of two formations in England—Red Sandstone and Magnesian Limestone—but of three in Central Russia. The organic remains are neither numerous nor very remarkable, but approximate far more closely to those of the Carboniferous system below, than to those of the overlying Triassic. The flora, consisting of land and marine plants, amounts to 183 species, embracing fucoids, calamites, coniferous trees, and silicified trunks of tree-ferns. The fauna amounts to 350 species, including 53 fishes. The trilobites and other higher forms of crustacean life have disappeared. In common with the other Palæozoic systems, the fishes are all characterised by *heterocercal* or unequally-lobed tails; whereas in all the systems above the Permian the *homocercal* or equally-lobed tail predominates—a form which is nearly universal in the 8000 species now existing. Reptiles are more numerous than in the Carboniferous system, and now embrace SAURIANS as well as Batrachians—*e.g.*, the *palaosaurus*, *protosaurus*, and *thecodontosaurus*, all of which are true air-breathing and land-inhabiting reptiles. The minerals embrace excellent building-stones, limestone, gypsum, lithographic stone, copper, and occasionally veins of galena and sulphuret of zinc. Permian strata are known to prevail in the north and midland counties of England, in the whole of eastern Russia, and over considerable areas in Ireland, France, Germany, and the United States west of the Mississippi. The physical aspect of Permian districts is by no means destitute of beauty and variety, though the scenery is sometimes tame and uninviting, and the soil well adapted for pasture and woodland.

7. **The Triassic System** derives its name from the fact that in Germany, where the system is highly developed, it consists of *three* well-defined formations—the *Bunter Sandstein*, the *Muschelkalk*, and the *Keuper*—the middle formation being wanting in England. With these formations we commence, on our upward march, the second great division of the fossiliferous strata, and hence named the **MESOZOIC**. At the close of the Permian system, an infinitely greater change took place in organic life than that which marked the ascent at any previous stage. All the species and most of the genera of the earlier races have now disappeared, and are replaced in the Trias by an entirely new series, the types of which are continued to the base of the Tertiary. Nature has entered on a new cycle, and everywhere the humbler forms of organic life have given place to forms more highly organised. It is to this system, and not to the Devonian, that we must now refer the remarkable reptiles, the *Telerpeton*, *Staganolepis*, and *Hyperadapedon* of the Elgin Sandstone. In the Trias formations on the Connecticut river, in New England, the footprints of no fewer than 23 species of BIRDS are enumerated by Dr Hitchcock, together with Chelonians, Batrachians, and other reptiles. The largest of these footprints are 22 inches long, 12 inches wide, with a proportionate length of stride: whether Birds or Dinosaurs, they must have been of colossal dimensions. In the Trias also occur the earliest traces of MAMMALS. In 1847, Professor Plieninger discovered in the upper beds of the Keuper formation, in Würtemberg, the molar teeth and bones of a small marsupial animal named *Microlestes antiquus*. In England, the animal remains are not very numerous (only 61 species); but on the Continent, one single formation (the *Muschelkalk*) has already yielded 222 species, and the St Cassian beds 744 species. The flora embraces equisetæ, calamites, ferns, cycadaceous and coniferous plants—the last two being exogenous. In England and Ireland this system is the great repository of rock-salt, the layers of which, in Cheshire, in some places attain a thickness of from 75 to 100 feet. It also yields sandstone for building purposes, calcareous flagstones, limestones, and valuable beds of gypsum. The scenery of the Trias is usually tame and monotonous, and the soil better adapted for pastoral than agricultural purposes.

8. **The Oolitic or Jurassic System** is highly developed in England, where it consists of three very distinct formations—the *Lias*, *Oolite*, and *Wealden*—and stretches slantingly across the country from Dorsetshire to Yorkshire. It is evident from the character of the embedded organisms that the first two are *marine* formations, while the last—which is often regarded as belonging rather to the overlying Cretaceous system—must have been deposited from *fresh water*. The characteristic fossils of the *Lias*—the lowest of the three—are cycadaceous plants, which occupy a middle position between ferns and coniferous trees, and which here make their first appearance. The fauna wears a singular aspect, owing to the vast number of ammonites, belemnites, gryphæ, and cuttle-fishes which it embraces. Reptiles also attain their highest development in this formation, containing, as it does, those gigantic and highly characteristic forms, the *Ichthyosaurus* and *Plesiosaurus*. In 1864, the fossil fauna of this formation, as developed in the British Isles, contained, according to Professor Ramsay, 467 species. The flora of the *Oolite* in the same year comprised 128 species—consisting, for the most part, of cycadaceæ, ferns, equisetaceæ, and pines; with the new orders, cyresses, yews, dammaras, thujas, and screw-pines. Such, indeed, was the abundance of vegetation in the Oolitic age, that not unfrequently it exhibits seams of workable coal, as at Brora in Sutherlandshire, and Richmond in Vir-

ginia. Its fauna was peculiarly rich and varied, as is evident from the fact that in the British rocks alone no fewer than 1483 species were known to geologists in 1864. The marsupial or pouched animals, which first appeared in the Trias, now existed in great numbers. They were allied to the living opossum and kangaroo of the Australian continent, and formed a connecting link between birds and the placental or true Mammalia. In the Stonesfield slate, a member of the great Oolite, are found the remains of the *Stereognathus*, a small quadruped which Prof. Owen regards as an herbivorous placental mammal; but this is somewhat doubtful. The *Wealden* derives its name from the "wealds" or "wolds" of Suffolk, because it prevails extensively in that county. Unlike the two underlying formations, the Wealden is essentially a freshwater formation, and the only one of that nature occurring within the limits of the Mesozoic series. It, no doubt, formed the delta of an ancient river of great magnitude, which flowed from an ancient continent that occupied the area of the present N. Atlantic. Its organic remains differ very widely from those of the Lias and Oolite—consisting of "the spoils of the river and the land, not of the sea." Among its most characteristic plants may be named the *Sphenopteris gracilis* (a sort of fern), leaves of *conifera* and *cycadacea*, and fruits resembling those of palms. Of the numerous reptiles belonging to the formation are—the *Iguanodon*, a gigantic herbivorous animal, and the *Pterodactyl*, or flying reptile, which somewhat resembled a bat. The minerals of the Oolitic system are of considerable importance, consisting of building, paving, roofing, and tile stones, alum, marble, coal, and fuller's earth. Both the Lias and Oolitic limestones are largely quarried for mortar and hydraulic cement, the latter also furnishing the best description of lithographic stones. The scenery of Oolitic districts is varied and pleasing, but wants the boldness and abruptness of Metamorphic regions. The soil is usually dry and fertile, except the Lias and Wealden clays, which in dry seasons are stiff and intractable.

9. **The Cretaceous System**, the highest in the great Mesozoic series of rocks, derives its name from the chalk (Lat. *creta*) that forms the main ingredient in its composition. It is a marine deposit, and embraces two well-defined formations—the Lower and Upper Cretaceous. The flora is not abundant, there being only 12 species known in British rocks, and even these usually consist of drifted and imperfect fragments. They exhibit, however, a great era in the progress of terrestrial vegetation, for here first occur the remains of true EXOGENOUS or DICOTYLEDONOUS TREES—i.e., trees having a separable bark, distinct concentric circles, increasing at their circumference, the solidity diminishing from the centre outwards, the pith enclosed in a longitudinal canal, and possessed of medullary rays. The fauna is rich, varied, and beautifully preserved. Nearly all the types of life are strictly and peculiarly Mesozoic. "Of the 521 species known in our Upper Chalk, all, with the exception of *Terebratula caput-serpentis* and a few foraminifera, have apparently become extinct during that vast period that elapsed between the close of the Cretaceous and the beginning of the Eocene epoch in England."—(Professor Ramsay.) Of the four orders into which fishes are divided, two appear for the first time in Cretaceous rocks—viz., CTENOIDS and CYCLOIDS—i.e., Bony Fishes or Teleosteans. Reptiles, though still the dominant class of animals, have now passed their meridian; but turtles, pterodactyles, and oviparous saurians are not unfrequent. Bones of wading birds have been detected in N. America; but the Quadrumanous Mammals, formerly supposed to belong here, do not really appear before

the Eocene formation, immediately above. Altogether, 1362 species of fossil animals were known to exist in British rocks in 1864, of which 89 were fishes and 31 reptiles. Cretaceous strata cover extensive areas in the south of England, in France, Germany, the United States, and Vancouver Island, in all of which the scenery is distinguished by the rounded outlines of the hills and valleys, which afford excellent pasturage. They are now known to be derived from the myriads of coralline zoophytes and foraminifera with which the seas of the period abounded. Similar deposits are being formed at the present day in the bed of the ocean (see p. 52). The industrial products of the Cretaceous formations are comparatively unimportant, consisting chiefly of preparations of chalk and flint. The former, which consists of carbonate of lime, is employed by the farmer, bricklayer, and plasterer; while the latter, when calcined, is largely used in the manufacture of flint-glass and porcelain ware.

10. The Tertiary or Cainozoic System embraces three formations—the Lower, Middle, and Upper—or, as they are more commonly called (with reference to the number of species which they respectively contain in common with our existing fauna), Eocene, Miocene, and Pliocene. These consist of vast and varied deposits—fluvial, lacustrine, marine, and volcanic—usually found resting on one or other of the formations of the Cretaceous system. It appears evident that during their deposition important changes took place in the relative level of sea and land, especially in the northern hemisphere; that volcanic agency was developed on a vast and magnificent scale; that the portion of Europe now forming the British Isles was the site of enormous lakes, which at the present day have their best analogues in the vast fresh-water lakes of Canada; and that, during the same epoch, such a gradual refrigeration of climate took place in European countries as to admit of the existence of plants and animals similar to, or identical with, those now existing in that continent. On entering the Tertiary strata the palæontologist finds that organic nature has undergone a complete change—that every plant and animal with which he became acquainted when studying the Secondary rocks has passed away, and that he has now entered on a wholly new stage of existence. Never before, during the pre-Adamic history of our earth, did so thorough and total a change take place in the flora and fauna of the globe. The former is distinguished from that of the older epochs by the abundance of dicotyledonous trees (oaks, beeches, elms, &c.); the monocotyledons, especially palms, also become greatly more numerous; while the conifers, previously so abundant, no longer occupy a prominent place. In the Eocene formation alone, in which between 200 and 300 fossil plants have been detected, no fewer than one-half are dicotyledons. The fauna of the system is equally characteristic. It was pre-eminently the age of mammalia; for, though mammals, both marsupial and placental, are known to have existed in the Secondary ages, only a few vestiges of either occur in formations lower down than the Eocene. In this single formation—that to which the London and Paris basins belong—no fewer than 25 genera of this class of vertebrata were known in 1856. Altogether, upwards of 100 genera of mammals occur in the Tertiary rocks; and, what is still more remarkable, all the existing orders of the class are represented. The pachydermata were especially numerous, embracing the uncouth *palæotherium*, *anoplotherium*, *deinotherium*, *mastodon*, and *mammoth*. It was among the pachydermata of the Paris basin that the illustrious Cuvier effected those wonderful restorations which, in the beginning of this century, gave such an impetus to palæontology. All, or nearly all, the existing orders of birds

have been detected in Eocene beds, the most remarkable being the gigantic *gastornis Parisiensis*, a form intermediate between the wading and aquatic orders. The reptiles resemble the existing crocodile, alligator, and gavia. The fishes embrace the four orders—placoids, ganoids, cycloids, and ctenoids—but appear to be almost without exception of different species from those now peopling the ocean. In England, Tertiary strata cover nearly all the basin of the Thames, as also Hampshire, and the northern part of the Isle of Wight; but they scarcely exist in Scotland and Ireland. The industrial products are various, comprising building-stone, marble, limestone, gypsum, brick-clay, potter's clay, pipe-clay, millstones, lignite, and amber.

11. **The Quaternary or Post-Pliocene.**—It would appear that, after the deposition of the Eocene, Miocene, and Pliocene formations, a great change took place in all the higher latitudes of the northern hemisphere in regard to the relative distribution of sea and land; that a large portion of Europe and of the British Isles was gradually submerged beneath the waters, the summits of the loftier mountain-ranges appearing as islands in mid-ocean; that a corresponding elevation of land occurred simultaneously in the Arctic regions, accompanied by a change in the direction of the great ocean-currents, and by a great diminution of temperature over all northern Europe; that enormous icebergs—laden with gravel, sand, and gigantic boulders—were annually disengaged from the Arctic shores, and, floating southwards, discharged their miscellaneous contents over the recently submerged lands; that this submergence and accompanying change of temperature caused the destruction of by far the greater number of the plants and animals which existed in north Europe in the Miocene and Pliocene ages—their places being supplied, however, to some extent, by the fauna and flora now peculiar to more northern latitudes; that after this state of things had continued for ages, the submerged lands of north Europe and the British Isles were again gradually elevated to their present level; and that, finally, the glacial epoch having passed away, a new flora and fauna, suited to the new conditions, made their appearance—many of the species of which continue to exist to the present day. The organic remains are by no means numerous. In the British Isles they occur chiefly in the Norwich Crag, Lancashire, north Wales, Isle of Man, the banks of the Clyde, Caithness, and in the north and east of Ireland. On the Continent the main localities are Scandinavia, Russia, and North Germany; while similar deposits are found in Sicily, North America, Patagonia, and Tierra del Fuego. Quaternary beds contain very few recognisable remains of plants, but some of the species still exist among our aboriginal trees; as, for example, the Scotch fir and the common birch. The fauna is more abundant, but consists for the most part of mollusca; though in the fresh-water beds numerous remains of mammals occur, the greater number of which have become extinct. No fewer than 37 species of mammals are enumerated by Professor Owen as occurring in the caves of the British Isles; and of these, he says, 18 species have become extinct, while the remaining 19 continue to survive in the British archipelago, or on the Continent. The entire fauna of the glacial beds, as given by Dr Edward Forbes, amounts to 170 species. These are chiefly mollusca, but the number includes several birds, and not a few extinct mammals; but the horse, goat, ox, red deer, badger, fox, wild-cat, and several other species known to have existed in the Pliocene era, survived the storms of the Post-Pliocene, and now form a living bridge connecting the present epoch with the immeasurable ages of the past.

12. Recent or Prehistoric Formation.—A deeper interest attaches to this formation than to any other in the entire geological scale. Here are found the earliest traces of the existence of MAN on the earth—as pile-dwellings, tree canoes, flint arrow-heads, and other stone implements manufactured by human hands. No clear line of demarcation separates this formation from the Post-Pliocene, and in the present state of science it cannot be positively determined in what century or millennium those implements were fabricated. There can be little doubt, however, of the vast antiquity of some of them, as shown by Sir Charles Lyell and others. The antiquity of the human species, as thus indicated, no doubt conflicts with the chronology of Usher, founded on our modern Hebrew text. In the matter of antediluvian chronology, however, the Hebrew text has in all probability been tampered with, as we have shown at large in a separate work ('Facts and Dates,' p. 62-69). The Septuagint translation—a translation sanctioned by our Lord and His apostles—assigns to our race an antiquity of nearly 1500 years more than Usher does. Science is giving its emphatic verdict, in this particular, in favour of the Septuagint; and though the extended chronology may fail in meeting all the difficulties of the case, it will certainly meet many of them. In the meantime we cordially adopt the words of a recent brilliant writer when he says, "The theology of science is at present in its infancy, and consequently liable to multitudes of errors. When the theologian shall have become more conversant with God's works, and the scientific man more of a theologian, we shall obtain more light."—('Old Bones,' by Rev. W. S. Symonds, F.G.S.)

Antiquity of the Earth.—Modern science has attempted to solve this apparently insoluble problem. Calculating from the rate at which molten lava is known to cool, Professor Helmholtz estimates that our planet could not cool down from a temperature of 2000° Cent. to that of 200° Cent. (360° Fahr.) in less than 350 million years. Scores of millions more must have elapsed to reduce it to 200° Fahr., which is regarded as the highest temperature at which vegetable or animal life could commence. Thousands of millions of years are claimed in addition, by some geologists, for the time since life began; but Sir William Thomson, proceeding on other physical data, reduces the last item in the account to the modest sum of 100 million years. Adding these periods together, we obtain something approximating to 500 millions of years since time began.

Evidence of the vast antiquity of the globe, and even of its *solid crust*, may be found in other directions. It is a well-known fact that the Falls of Niagara are slowly but constantly receding backwards, or upstream. They are now six miles nearer Lake Erie than they once were. Geologists are not unanimous as to the rate of retrocession, some estimating it at 1 foot per year, others at only 1 inch. The former estimate gives 31,000 years as the time in which the river has excavated the six miles referred to, but the latter, 372,000 years. Again, it is well known that the coral insect carries on its operations within a few fathoms of the surface of the sea; yet reefs are not unfrequent in the Pacific Ocean which reach to a depth of 2000 feet. The bottom must therefore have been gradually sinking ever since the formation began. Geologists

maintain that the rate at which these insects build is only one-sixteenth of an inch annually ; and that therefore they must have taken 384,000 years to complete a reef of such immense thickness. But if, as is further maintained, these reefs were not commenced till the beginning of the Tertiary age, what an inconceivable length of time must have elapsed since the formation of the first stratum of the fossil-bearing rocks, which are calculated to have an aggregate thickness of 20 miles ! The data, however, on which these estimates have been formed, are far from being clearly established. Geologists are too apt to toy with millions of years as if they were playthings, and to show no regard to moderation or common-sense. Science has not, hitherto, been able to determine the actual antiquity of the planet, and probably never will.

X.—OPTICAL INSTRUMENTS.

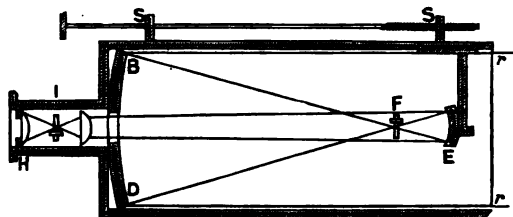
Our knowledge of external nature has been brought to its present advanced state for the most part by the employment of artificial contrivances. Foremost among these are three optical instruments—the telescope, microscope, and spectroscope—by the combined aid of which our ideas regarding the extent, nature, laws, and perfection of the material universe are immeasurably in advance of the crude conceptions of the ancients. The telescope practically brings the most distant objects in nature near to us ; the microscope so magnifies the minutest objects that they can be clearly seen by the eye ; while the spectroscopic, the most marvellous invention of modern times, gives us, for the first time, distinct ideas regarding the true *nature and constitution* of the most distant heavenly bodies.

The Telescope.—Among the instruments named, the place of honour must be assigned to the telescope, an instrument which, as its name indicates (*tele*, at a distance ; *scopeo*, I view), enables us to see very distant and even invisible objects with all the distinctness with which we can see those which are near us. The exclusive honour of its invention, as is the case with nearly all great discoveries, can be claimed by no single individual ; but the first really useful telescope was constructed by Galileo in 1609, while in the year following he had his brilliant reward in being the first mortal who beheld the satellites of Jupiter, the rings of Saturn, and the phases of Venus. Telescopes are of two kinds—refracting and reflecting. In the former, an image of a distant object is produced by a *converging glass lens* ; in the latter, by a *concave metallic reflector*. Galileo's telescope was of the former kind, the Gregorian and Newtonian of the latter. A refracting telescope, in its simplest form, consists merely of a large double-convex glass lens, which forms a very small image of the distant object at its focus (hence termed the *object-glass*), and a second

smaller double-convex lens (called the *eye-piece*), which is used as a microscope (*micros*, small ; *scopeco*, I view) to magnify the image formed by the first. The image of the object seen in the focus of the larger lens arises from what is termed the *refraction of light*. To illustrate this properly, suppose I place a florin at the bottom of a stone jug placed on a table, and then step backwards until I can no longer see the piece of money. Let some one now pour water into the jug ;—instantly the florin becomes visible. Here we have a simple example of refraction. The ray of light from the florin proceeds in a straight line through the water, but is bent in a new direction on quitting the liquid and commencing its passage through a rarer medium. The same thing would happen if a ray of light proceeding from a planet entered the surface of a thick transparent glass. It will move in a straight line from the object to the glass ; on reaching the glass it is bent or *refracted* in a new direction, while, after passing through the glass, it resumes its original direction, though it is no longer in the same line. Next, suppose that the glass, instead of being flat and of a uniform thickness, is wedge-shaped like a *prism* (see diagram, p. 130). In passing through such a body, it will be observed that the ray is bent *towards the thick end* of the wedge. Let us now once more vary the form of the piece of glass : instead of being wedge-shaped, as before, let it be circular, but greatly thicker in the middle than at the circumference. A piece of glass ground into this shape is called a *lens*. If such a lens be set up on its edge, and the sun's rays be allowed to fall on one side, the rays will be individually bent out of their original parallel direction towards the central or thickest part of the lens, and on reaching the other side of the glass will be deflected again, and made to converge at a point called the *focus*, more or less distant from the lens. At this point two interesting phenomena are exhibited : 1, The heat is very intense ; and, 2, A small but very bright image of the sun becomes distinctly visible by means of the microscope. Such a combination of two glasses—one giving a true image of a distant object, and the other magnifying that image—is called a telescope. The reflecting telescope differs in principle from the refracting, and possesses some advantages over it. In order to obtain an image of a distant object, the rays of light, instead of being made to pass through a glass lens, are *reflected* from the inner surfaces of concave metallic mirrors. There are four kinds of reflectors : 1, The Gregorian, invented in 1663, by James Gregory, Professor of Mathematics at Aberdeen, but not actually constructed till 1674 ; 2, The Newtonian, invented by Sir Isaac Newton in 1669 ; 3, The Cassegrainean, invented by a Frenchman in 1672 ; and, 4, The Herschelien, invented by Sir W. Herschel in 1786.

The annexed diagram is a section of the Gregorian reflector. B D is a concave metallic mirror, formed by the revolution of the hyperbolic curve, and having a small orifice in its centre. E is a small elliptical mirror placed in the axis of the larger one, and at a distance from it of a little more than the sum of their focal lengths. At H are two plano-convex eye-lenses, with the plane side towards the eye, while S S is a screw which moves the small mirror to and from the greater one. Let r B and r D be two parallel rays from a distant object : these

will be reflected to F, the focus of the larger mirror, where an image of the object will be formed, and the rays, crossing each other, fall on the smaller mirror, E,

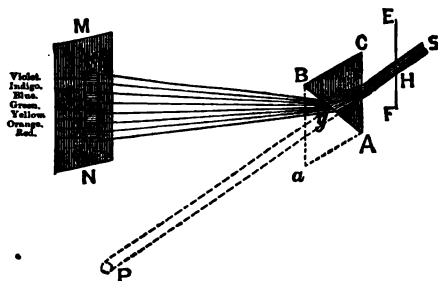


The Gregorian Telescope.

which sends them in a parallel direction to one of the lenses, H, which refracts them, and makes them converge at a focus, I, midway between it and the eyepiece H, which acts as a magnifier.

The following is a convenient rule for calculating the magnifying power of reflectors: "Multiply the focal distance of the large mirror by the distance of the small mirror from the image; then multiply the focal distance of the small mirror by the focal distance of the eye-glass; and divide these two products by one another, and the quotient is the magnifying power."

The Solar Spectrum.—In the previous paragraphs we have regarded light as a simple substance, all the parts of which were equally refracted. This, however, is not its constitution. It was one of Newton's simplest and yet greatest discoveries, that, when a beam of white sunlight passes through a prism, it is divided into seven constituent rays, each of which possesses a different degree of refrangibility, a different wave-length, and a different time of vibration—for these three properties vary together—in virtue of which their



Solar Spectrum.

paths, when they pass out of the glass prism, differ in direction. He found white light as emitted from the sun, or from any luminous

body, to be composed of seven different colours of light—viz., *violet, indigo, blue, green, yellow, orange, red.*

In the accompanying diagram let H be a small hole in the window-shutter, E F, of a darkened room, and S H a beam of sunlight passing through it. The beam will go in a straight line and form a round white spot at P on the opposite wall. But if we now interpose a prism, B A C, so that the beam of light may fall on its first surface C A, and emerge at the same angle from its second surface B A at the point g; and if we receive the refracted beam on a white screen M N, then, instead of a white spot, there will be formed upon the screen an oblong image, K L, of the sun, containing the seven colours already mentioned. This lengthened image of the sun is called the *solar* or *prismatic Spectrum*.

It will now be seen that the red ray has been the least refracted, and the violet the most, the whole presenting a rainbow-tinted ribbon, only that the streaks or stripes are crossways, instead of longitudinal. No *lines* are seen across the spectrum thus produced, and it is extremely difficult for the sharpest eye to point out the boundary of the different colours. At the lower end the red is comparatively faint, but becomes brighter as it approaches the orange. The light increases gradually to the middle of the yellow space, where it is brightest, and from this it gradually declines to the upper or violet end of the spectrum, where it is exceedingly faint. It is an interesting fact that the limits of visibility are not the true limits of the space to which the solar action extends. The rays of light are accompanied by heating rays, as also by chemical or actinic rays (*aktis*, a ray), and these three are far from being uniformly distributed along the spectrum. Sir W. Herschel found that the maximum of heat comes from *beyond* the red end of the spectrum, but is not perceptible beyond the violet end. The actinic rays, on the other hand, are most energetic near the violet extremity, between the lines G and H (p. 133), and exist in that direction considerably beyond the limits of the spectrum. Before passing from this we may show how it explains two well-known phenomena in nature—the rainbow and twilight.

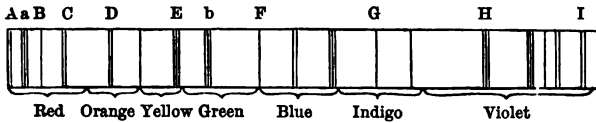
The Rainbow is perhaps the most beautiful meteor in nature. It can be seen only when the sun is shining on one side, rain falling on the other, and the spectator in a straight line between the sun and the centre of the rainbow. Water, like glass, *reflects* some rays, while it transmits or *refracts* others. Every drop of the falling rain acts like a lens or prism in decomposing the solar beam into its seven component rays, and in refracting some of them more than others. If we place a globe of glass or water on a level with the eye, and opposite to the sun, we instantly see a prismatic spectrum reflected from the further side of the globe, having the *violet* lowermost and the *red* uppermost. Now, since in a shower of rain there are myriads of drops or small spheres of water in all positions relative to the spectator, his eye will receive spectra inclined at all angles, so that, when combined, they will form the large circular spectrum called the rainbow. To have a right conception of the phenomenon, we have only to bear in mind that the eye of the spectator is stationary, while the drops are in rapid motion. Under favourable circumstances, two bows are seen, an inner and an outer; but in the latter the colours are reversed, in consequence of their being produced by two reflections and two refractions.

Dawn and Twilight.—If the earth had no atmosphere, day and night would succeed each other without any interval; but the earth being surrounded by an aerial envelope, more than 100 miles deep, and gradually increasing in density with the depth, such rapid alternations of light and darkness are avoided. To understand this, let us trace the progress of the sun's rays at early dawn, and while that luminary is still several degrees below the horizon. Through the 92,000,000 of miles which separate the sun from our atmosphere, the rays travel in a straight line, and with a velocity of 186,000 miles per second. On arriving at the upper strata of the atmosphere, some of the rays are *reflected* back as from a mirror, but the remainder are bent or *refracted* downwards, in the direction of the earth's surface. The further they advance in this direction the more they are bent downwards, because the density of the air is continually increasing, and by the time they have arrived at any spot on the surface they have travelled through a parabolic curve, one limb of which rests on the surface at the spot indicated. Here the sun will appear at or above the horizon, and in the direction of a tangent to the curve at that spot; for the eye necessarily estimates the direction of a body from the direction of the rays of light proceeding from it *at the moment they enter the eye*. The sun, in consequence, always appears higher up in the heavens than he really is, the difference being greatest where his actual elevation is the least. Within the tropics, where he rises and sets in a direction nearly at right angles to the line of the horizon, both dawn and twilight are very short; but as we proceed to higher latitudes he descends more obliquely, and the interval between day and night is proportionally increased. The twilight ends when the sun has sunk from 18° to 21° below the horizon, for then his rays cease to be perceptibly refracted. In the Arctic regions, where the sun's elevation in summer is never very great, and where he is wholly absent for long periods in winter, he is seen at returning spring skimming the horizon for several days before his disc has actually ascended above it. The refractive power of the atmosphere (water being taken as unity) is .000589. The property of refraction was discovered by Willebrod Snell, a Dutch geometrician, about A.D. 1624, and the beautiful law that governs it by M. Fresnel, a French physicist, about 1826.

Spectrum Analysis.—In the solar spectrum as produced by Newton (p. 133), the seven colours gradually merge into each other without any gap or line of demarcation being visible. Wollaston, in 1802, was the first who succeeded in showing that there are actual chasms in the spectrum. By making a narrow slit in the window-shutter, instead of a round orifice as Newton did, he found that two dark spaces appeared in the spectrum, parallel to the slit. In these two spaces lay the germ of the most marvellous discoveries of modern times. Fraunhofer, a German optician, was the first that distinguished himself in the new field of inquiry. Wollaston looked at the spectrum with the naked eye, Fraunhofer employed the telescope; the former had seen but two lines—the latter, in 1814, saw and mapped out no fewer than 576. The position of Fraunhofer's principal lines is indicated in the following diagram.

The student will do well to bear in mind the position of these principal lines, as he will thereby be able to follow intelligently the accounts of spectroscopic researches. He has only to remember that

A B C belong to the red portion of the spectrum, D to the orange-yellow, E to the yellowish-green, F to the greenish-blue, G to the



Spectrum Analysis.

A is a well-marked line at the red or lower end of the spectrum, where the colour is barely visible. B is a clearly-defined red line of perceptible breadth. Between A and B is a band of several lines called α . C is a strongly-marked dark line. D consists of two strong lines very near each other. E is a band of several lines, the middle one being stronger than the rest. At b are three strong lines, the two nearest F being somewhat apart. F, G, and H are also strong lines, while I is the violet end of the spectrum.

indigo, and H to the violet. Fraunhofer having ascertained that all these lines were found in the solar spectrum, of whatever substance the prism was formed, he next proceeded to examine the spectra formed by light from other sources. In the case of solar light, *reflected* from the clouds, moon, planets, &c., he found the number and positions of all the above lines the same as when the light proceeded directly from the sun. The spectra of the fixed stars exhibited dark lines resembling those of the sun (see p. 17), but none of them had a spectrum exactly like it. Some of the lines were wanting, others were less distinct, while others still exhibited new lines. From this he concluded that the dark lines in every case are due to some peculiar property inherent in the light of the various heavenly bodies. Finally, he found that the spectrum from the flame of a lamp or candle is continuous, and not crossed by dark lines, but a bright double line is seen in the exact place occupied by the double dark line D in the solar spectrum. It was afterwards found that this double bright line is due to the presence of the all-pervading element, sodium, in the flame. An incandescent solid or fluid—as, for example, a piece of metal heated till it glows with a white heat—shows a continuous spectrum; but with glowing vapours the case is wholly different, as their spectra exhibit numerous coloured lines or bands. The electric spark, again, yields a very variable spectrum, depending upon the nature of the metallic conductors and the medium through which it is seen, for it includes the spectrum of the vaporised substance of the conductor as well as that of the gas or vapour through which the discharge takes place. It is in this way that a large number of elementary bodies have had their respective spectra assigned to them.

Hitherto we have been considering the actual spectra of luminous objects; we have now to inquire into the effects produced on these spectra when the light which forms them is allowed to pass through absorbing media. Sir David Brewster found that when ordinary solar light is transmitted through the thick vapour of nitrous gas, a number of new dark lines are seen towards the violet end of the

spectrum, and parallel to the Fraunhofer lines. It had been noticed by Fraunhofer that the two orange-coloured lines found close together in the spectrum of the glowing vapour of sodium coincide in position with the two dark lines D in the solar spectrum. Kirchhoff, having a **spectroscope** consisting of four flint-glass prisms of great dispersive power, determined to inquire whether this coincidence was exact. Having obtained a bright solar spectrum, he brought a flame, coloured by sodium vapour, in front of the slit, and then saw to his astonishment that the dark lines D changed into bright ones. Here he had shining through the slit two kinds of light—sunlight and the light of the sodium flame. The former alone would have given the ordinary solar spectrum with the D lines of a certain degree of darkness; the latter alone would have given bright lines in the same position. He naturally expected that the bright lines of the sodium spectrum would at least partially reduce the darkness of the corresponding D lines in the solar spectrum. Instead of that, however, these lines actually appear darker. With the view of testing this remarkable result, he exchanged the sunlight for the oxy-hydrogen lime-light, which, like that of all incandescent solid or liquid bodies, gives a spectrum containing no dark lines. When this light was allowed to fall through a flame coloured by common salt (sodium chloride), dark lines were seen in the spectra in the position of the sodium lines. This result was more striking than the former one, inasmuch as the two lights seemed to produce darkness. These experiments of Kirchhoff involved one of the most important truths ever discovered. He at once inferred that sunlight, which shows these same dark lines, must, before reaching us, have passed through the vapour of sodium. Either in our own atmosphere or in that of the sun, this familiar metal must exist in quantities sufficient to cause the observed absorption lines. Moreover, those countless other lines which cross the solar spectrum must each indicate some process of absorption, exerted by vapours on the solar atmosphere or on ours. Finally, he argued, since the presence of sodium has thus been demonstrated in the sun, why may not the presence of other elements be in like manner rendered apparent? He therefore compared the spectrum of the luminous vapour of iron with the solar spectrum, and found to his amazement, that precisely as the two sodium lines coincide with the D lines of the solar spectrum, so every one of the iron lines had its counterpart in that spectrum—line for line. Here, then, lay the incontrovertible evidence that the vapour of iron exists in the solar atmosphere. Thus, one after another of the elements enumerated at p. 5, together with aluminium, manganese, and cobalt, were discovered as existing in the great luminary of day.

Nebulae.—One of the most brilliant results of spectrum analysis is the evidence it adduces respecting the present condition of *non-terrestrial matter*, and especially the light it throws on what is called “the nebular hypothesis.” Nebulae generally present the appearance of self-luminous or phosphorescent patches of matter, in a highly dilated or gaseous state, and scattered irregularly in all

directions through the remote heavens, but richest in the regions farthest from the Milky Way. Altogether, about 3700 nebulae are known, which may be divided into two great classes: 1, Those resolved by powerful telescopes into mighty clusters of minute stars; and 2, Those which cannot be so resolved. The first class exhibit spectra similar to those of the sun and his brother luminaries; while the spectra of the second class are such as would be produced by glowing gaseous matter, exhibiting three bright lines—one the F line of the hydrogen spectrum, and another a line of nitrogen. This great difference among the nebulae being established by the spectro-scope, it becomes a question whether those which are gaseous do actually *aggregate* in the course of ages, so as to form clusters of stars, and whether all the orbs in the stellar universe existed originally in the gaseous form. But, in the present state of astronomical science, no decided answer can be given to these questions. Many varieties of nebulae exist within the limits of the sidereal system. Some undergo extensive variations, as that which surrounds *Eta Argus*; others have completely disappeared; while others still have recently come to view where formerly no nebulosity was discernible.

The Nebular Hypothesis.—The great German philosopher, Immanuel Kant, maintained, about a century ago, that the planetary bodies of the solar system, all rotating and revolving in the same direction, seem to have been created together, and to owe their motion to a single impulse. Sir W. Herschel suggested that the formation and growth of sidereal bodies are constantly going forward by the aggregation of nebulous matter; and La Place, the great French mathematician, attempted to trace, from purely physical laws, the mode of operation of this development. "He showed that a mass of gaseous or fluid matter, if made to rotate rapidly, would spread out in the plane of rotation, and become a thin disc, growing thinner and wider as the velocity of its rotation increased, till at length centrifugal force getting the better of cohesion, whole rings or fragments of the edge would fly off, and, contracting by gravitation into spheroidal masses, would continue to revolve round the centre from which they broke off. In these liberated masses the velocity of the outer edge would exceed that of the inner; and this excess of velocity on one side would give the newly-formed spheroid a rotation on its axis. This process might be repeated again and again with the same stratum—the successive spheroids revolving in continually narrower orbits—till at last the nebula is replaced by a system of compact planetary bodies. In like manner separated spheroids might, in the earliest stage of formation, throw off one or more fragments to become satellites." This splendid conception of La Place will undoubtedly account for not a few of the phenomena observed in the solar system. For example, it enables us to see why the remotest planets, formed of the most volatile and rapidly-moving matter, are also the largest and least dense, while the heaviest and smallest are near the centre. It fails, however, in explaining far more than it accounts for. It assigns no reason for the vast varieties of size observed among the planetary bodies; for the remarkable variations of inclination of their axes and orbits; for the retrograde motion of the satellites of Uranus and Neptune; for the density of Jupiter's satellites being greater than that of their primary;

for the great inclination and eccentricity of many of the asteroids; and, above all, for the observed peculiarities of motion of those cometic and meteoric systems which we must now regard as regular members of the solar system (pp. 12, 13). Moreover, according to this theory, Neptune must have been formed millions of ages before Uranus; Uranus as long before Saturn; Saturn before Jupiter—and so on. But as a matter of fact, the appearance of those members of the solar system which we are best able to study does not indicate any such enormous disproportion in their relative ages, but rather seems to show that they were formed at the same time; and the origin and secular increase of size of the different planets may be accounted for, according to Mr A. B. Proctor, in a wholly different way (see p. 14). So far from Jupiter and Saturn having an enormous antiquity, as compared with the earth, these planets have not yet had time to cool down, but appear to be in a state of dull-red heat; while the rings of Saturn, which are often referred to as affording proof of La Place's theory, must now be regarded as evidence on the other side (p. 10). Again, why should Venus be less dense than the earth, which is more remote from the sun, or Saturn less dense than Uranus? For our own part, we believe that the forces which are at work in nature are not inherent in matter, but in that Almighty Being who not only summoned matter into existence, but who continues to sustain it in being and in the possession of all its properties. We further believe that material objects can never become the ultimate fountains of any species of power, and that MIND IS THE TRUE SOURCE OF ALL POWER AND OF ALL MOTION.

Atmospheres and Temperatures of the Planets.—As yet no trustworthy evidence has been obtained as to the existence of an atmosphere in the two planets nearest to the sun, or in the two most remote. That Venus has an atmosphere of considerable height and density is clearly established by observations taken at her last two transits. This atmosphere Vogel has analysed with the spectroscope, and found it to contain aqueous vapour. Owing to the planet's axis inclining 75° from the perpendicular, the seasonal differences of temperature must be extremely excessive, and wholly incompatible with the existence of any species of living beings with which we are acquainted. Of all the planets of the solar system, Mars most resembles our earth, presenting as he does continents and oceans, as well as polar regions permanently covered with snow, while the spectroscopic observations of Mr Huggins show that his atmosphere is charged with the vapour of water. His axis being deflected from the perpendicular considerably more than in the case of our earth, his seasonal changes must differ correspondingly. The planets Jupiter and Saturn resemble each other in many particulars: they far transcend our earth in mass and volume; they are adorned with magnificent systems of subsidiary bodies; they are surrounded with a very deep vapour-laden atmosphere; they are crossed with cloud belts of great depth, so that it is doubtful whether anything has ever been seen of the real surface of either planet; while, finally, they both appear to be expiring suns, no longer shining with all their wonted light, but still capable of yielding important supplies of heat to the tiny orbs that revolve around them, which possibly may be the abode of living creatures.

XI.—HOW TO FIND THE DISTANCE OF THE HEAVENLY BODIES.

All our knowledge of the distance and magnitude of the celestial bodies is derived from what is known as Parallax—*i.e.*, the apparent change of position in an object arising from a real change in the position of the observer ; in other words, it is the angle formed at the object by two straight lines drawn from it to the two points from which it is observed.

Parallax.—Suppose we want to find the distance of the moon from the earth, let us seek out two places widely apart, and as nearly as possible on the same meridian,—say Greenwich and Cape Town. We shall find, there is a sensible change in the position the moon apparently occupies on the background of the sky, the line joining the two places being used as a base line, and observations made on the moon at each end of it. The result is that the moon's mean horizontal parallax is $57' 2''.70$, and therefore her mean distance 238,818 miles. In general, the parallaxes of the planets are quantities far too small to be directly observed ; that of Mars, however, when in opposition with the sun, amounts to $24''.6$. As seen from the sun, the earth's diameter is so small that it becomes useless as a base-line, and consequently the sun's distance cannot be thus determined. But “when Venus is at her inferior conjunction, and at the same time very near either node, her body will be projected on the sun's disc, and through the effect of her proper motion combined with that of the earth, she will appear as a dark spot passing over the sun's disc, and describing a chord which will be seen under different aspects by spectators placed at different points on the earth ; because, by reason of parallax, they refer the planet to different points on the solar disc. The position of the spectator not only occasions a difference in the apparent path described by the planet, but has also a very sensible influence on the duration of the transit ; in consequence of which the parallax, and therefore the distance of the sun, can be determined with great exactness.” The following sketch of the progress of this problem towards solution may interest the student.

The Transit of Venus.—In 1874, the various Governments of Europe and America made gigantic preparations to observe accurately, and from many points of the earth's surface, that transit of Venus across the sun's disc which took place on the morning of the 9th December of that year, with the view of ascertaining the sun's correct parallax. To many it may seem strange that such efforts should have been made, and such sums lavished, for a purpose apparently so trivial as taking accurate note of the passage of a little dark spot over the face of the sun. But if we take into account the great advantage to be derived from this interesting occurrence, we must allow that all the labour and money have been wisely expended. By means of that transit astronomers hope to be able to solve, with greater accuracy than ever before, by far the grandest

problem in the whole range of the physical sciences—the distance of our planet from the sun. Assuredly no other problem is equal in importance to this, for on its solution depends our knowledge of the sun's magnitude and weight; the weights, sizes, and distances of all the planets in the solar system; and also the sizes, distances, and illuminating power of the innumerable fixed stars that spangle our heavens. To no other problem, therefore, have scientific men in all ages devoted such unremitting attention. But as it is the most important problem, so also it is confessedly the most difficult; and for whole millenniums of the world's history the most gifted of our species had no conception of what the answer would turn out to be.

Herodotus narrates the first recorded attempts in this direction. These were made not long before his own time (500 B.C.), and were believed in by both himself and his contemporaries, though they placed the sun at no greater distance from the earth's surface than ten miles. Fifty years later, Anaxagoras, the Ionian, estimated the sun's size as equal to that of the Peloponnesus, and, consequently, his distance as 18,000 miles. A century and a half later, Aristarchus, the astronomer of Samos, attempted the problem from a new direction (the moon's dichotomy), and announced the distance to be nineteen times that of the moon from the earth, or upwards of 5,000,000 miles. This, though only about a nineteenth part of the actual distance, was the first attempt in the right direction. It is unnecessary to follow the blind gropings after truth that characterised the many centuries subsequent to Hipparchus and Ptolemy, who flourished—the one 150 years before the Christian era, and the other 150 years after it—and who, themselves great astronomers, were yet unable to advance any nearer to a true solution than the philosopher of Samos. During this long and gloomy night the human intellect enjoyed a profound repose, giving few other proofs of its vitality than the sophistries of the Schoolmen. At length, however, the European mind suddenly wakened up in unprecedented energy. Many grand events marked its awakening, as the invention of printing, the revived study of the ancient classical tongues, the discovery of America, and the Reformation in Germany. At the end of the sixteenth century science could boast of such intellectual heroes as Tycho Brahe in Denmark, Galileo in Italy, and Kepler in Germany. Until Kepler's time no man knew whether there was any connection between the distances of the various planets from the sun and the number of days occupied in their revolution. But this wonderfully gifted seer revealed to men three famous "laws," by one of which the distances and periodic times are so curiously related, that when you have ascertained the distance or periodic time of any one of them, and one of these elements in the case of any other, you can at once calculate the other element. Surely, if there be such a thing as inspiration in matters connected with science, we must believe that such men as Kepler and Newton were inspired. By means of the vastly increased power which the telescope and his own three "laws" gave him, Kepler made a fivefold nearer approximation to a true solution of our problem than had ever been done before. "The sun's distance," said he, "is not less than 26,400,000 miles. I should not like to say how many *more* it may be."

Kepler's "laws" astonished all the astronomers, the more so as it was seen that they afforded a new key to the solution of the great problem of the ages. It could be shown that if, by any means, the distance of Venus, for example, from the earth could be ascertained, then the earth's true distance from the sun could be at once determined. Kepler had

shown that the distance of Venus from the sun bears to that of the earth from the sun the proportion of 72 to 100; whence it follows that the distance of the earth from Venus bears to that of Venus from the sun the proportion of 28 to 72. The distance of Venus from the earth, however, is constantly varying; but the shortest distance clearly is when Venus is directly between the earth and sun—that is to say, when, to a spectator on the earth, Venus is crossing the sun's disc. Such transits, however, occur very seldom, and at curiously regulated intervals, forming, indeed, a series, the terms of which, in years, are 8, 122, 8, 105, 8, 122, &c. These, moreover, can only occur either in December or in June. The first predicted transit took place in 1631, but astronomers failed to observe it; the next happened in 1639, and was witnessed by numerous scientific observers; the third in 1761, the fourth in 1769, while the fifth occurred in 1874. Previous to this the last available transit took place, as we have said, in 1769, or 105 years ago. It attracted an amount of attention, both in this country and on the Continent, that reflects the highest honour on the scientific zeal of the philosophers of the last century. Scientific expeditions were despatched to numerous well-selected localities, and many skilful observers took part in them. The exact longitudes, however, of these localities had not been previously determined, and this single source of error seriously interfered with the accuracy of the experiments. Accordingly, owing to this and other sources of error, the various parties gave widely different estimates of the sun's distance, and there is ample reason to believe that they were all seriously in error. Delambre, the celebrated French mathematician, as early as 1789, took a mean of all the discordant results, and announced the sun's distance to be 96,100,000 miles. This result was received by all astronomers for many years; but in 1820, Encke, Bessel, and other German astronomers, using refined mathematical processes, corrected Delambre's estimate, and reduced it to 95,293,000. Almost every astronomer now living accepted this finding, till within the last ten or twelve years—the principal exception being Professor Henderson, first Astronomer Royal for Scotland, who, from his own observations taken at the Cape of Good Hope, insisted that the sun's distance must be reduced to 90,637,000.

In this uncertainty the question of the sun's distance remained till 1862, when the planet Mars, being "in opposition," afforded another and a good opportunity of forming an independent estimate of the sun's distance. Fully twenty-six independent sets of observations were taken, and all the improved methods of modern science were put in requisition. The Russian astronomer, Winnecke, combined all the results, and confidently announced the true distance to be 91,184,000, a result very slightly exceeding that of Henderson. In the same year, Foucault, an ingenious French investigator, made a series of interesting experiments on the velocity of light, which he found to be 185,000 miles per second, and from these, through the agency of the eclipses of Jupiter's satellites, and their difference of time as seen from opposite sides of the earth's orbit, he announced the distance of the sun to be 92,254,000. Professor Stone, of Greenwich Observatory, gives 91,400,000; Newcome, of the United States, 92,306,000; Hall (also of the United States), 92,442,000; while the grand mean adopted at the Greenwich and Paris Observatories, since 1864, has been 91,430,000 miles. An elaborate attempt, made by W. Petrie, Esq., London, in 1869, to assign the relative weight due to each of the many mean results, gives a final grand mean of 92,061,000 miles, with a probable error of 90,000 miles,

plus or minus. We cannot expect much greater accuracy than this by purely scientific methods, even including the herculean efforts put forth in 1874. Hitherto these have not been reported on by the various Governments, nor are they likely soon to be, as the real calculations are very difficult, and new sources of uncertainty have, it is understood, been discovered. The French savans, however, in order to gratify the justifiable curiosity of their countrymen, have issued an interim report. We extract the following interesting communication from an article on the sun's parallax, which appeared in 'Les Mondes,' under date 15th April 1875, and apparently from the pen of the editor: "M. Puiseux has communicated to the Academy the first results of the discussion, and of the reduction of the Venus Transit Observations made partly at the Isle of St Paul's, in the Indian Ocean, and partly at Pekin. The number or final sum given by the Observations for the Solar Parallax is $8''.879$. This is equivalent exactly to the set of figures indicated by the Gt. Pyramid, which gives its meaning, however, in a more grand as well as more useful and generally intelligible form—viz., as the linear direct distance of the earth from the sun [see p. 8]. M. Puiseux gives his Parallax number as being very exact; the probable errors will not touch the second fractional figure." Well may the editor exclaim, "*La Grande Pyramide a vaincu!*"

XII.—MAP-PROJECTIONS AND GEODETICAL SURVEYS.

It is obvious, from the spherical form of the earth, that its surface can be best represented by means of the artificial globe; but even the largest globes do not admit of minute details, besides being both expensive and inconvenient. Hence, although no contrivance can reduce a curved surface into a plane without distorting some of the parts, we are obliged for particulars to have recourse to maps. A map is a plane representation of a sphere, or any part of it, and aims to show the form and dimensions, as well as the relative positions and proportions, of the various countries of the world, just as they would appear to a spectator looking down upon them from a balloon. There are five principal methods of projection—viz., the Orthographic, Stereographic, Globular, Conical, and Cylindrical. In the first three the *plane of projection*, or the flat surface on which the map is drawn, is supposed to pass through the centre of the globe; but in the Orthographic the eye of the observer is supposed to be at an immeasurable distance from it; in the Stereographic it is presumed to be at the surface of the globe, and exactly opposite the central point of the map; while in the Globular, it is supposed to be placed at a point whose distance from the surface of the sphere is equal to the sine of the angle of 45° .

The Orthographic.—In this projection, as all the parallels are in planes perpendicular to the plane of projection, they will be represented on the map by straight lines, while all the meridians, except the central one, will appear as elliptical curves. But as this method contracts the margins, and is only *optically* true, it is seldom used except for maps of the moon, which always presents to us the same face.

The Stereographic.—In this projection, owing to the proximity of the eye to the globe, the lateral parts of the hemisphere opposite the eye are enlarged, while those in the centre are contracted. This inequality, however, is not so great as to counterbalance the other advantages of this projection, which is generally adopted for Planispheres or maps of the hemispheres.

The Globular.—We have seen that the Orthographic projection contracts, while the Stereographic enlarges, the marginal portion of the map. In order to rectify these opposite defects, La Hire conceived that between the extreme positions of the eye in the two former projections an intermediate point of sight could be found by which their errors could be minimised. This point he found to be at a distance from the surface of the sphere equal to the sine of 45° , or $\frac{1}{\sqrt{2}}$ of the diameter. In this projection (see diagram, p. 34) equal spaces on the sphere are represented by nearly equal spaces on the map. The spaces may be made absolutely equal, in which case it is called the *Equidistant Projection*, which, owing to the great ease of its construction, is much used for representations of the two planispheres—some geographers preferring it, indeed, to the Stereographic. In all planispheres the projection is usually made on the plane passing through the 20th meridian W. of Greenwich, by which arrangement the continuity of the great continents, or the Old and New Worlds, is uninterrupted.

The Conical.—None of the foregoing projections is adapted to the construction of maps of continents or individual countries. For these the conical projection is invariably used. Suppose a paper cone to be placed upon an artificial globe (like an extinguisher on a candle) so as to make the cone coincide with the central parallel of the country which is intended to be mapped, and suppose the points on the sphere to be projected on the cone by lines drawn from the centre of the sphere. When this paper cone is spread out, all the distances along the mean parallel are as exactly laid down on the map as on the globe itself, while those on the extreme north and south parallels will be a little too long. In this projection the parallels are always arcs of circles, and the meridians straight lines drawn from the apex of the cone, or common centre of the circles.

Cylindrical or Mercator's.—For the facility of determining and laying down his course, the mariner requires such a projection as will enable him, while steering by his compass, to deal with *straight lines* only on his maps. This he could not do by any of the foregoing projections; for if he started from any point of the equator, for example, and steered in a N.E. course, his vessel would describe a spiral curve around the N. hemisphere. To meet this difficulty

Gerard Kauffman (Lat. *Mercator*, a merchant) devised a most ingenious method by which the meridians and latitude circles are represented in parallel straight lines. By the diagram (p. 18) it will be seen that the area of a sphere is equal to the convex area of the circumscribing cylinder A B C D—the point of sight being at S, in the centre of the sphere. In this projection the spaces between the parallels are enlarged as they recede from the equator, and consequently all countries in the vicinity of the poles are greatly distorted. The law of increase of the degrees of latitude renders it impossible to extend the projection to the poles, and hence Mercator's maps do not usually extend beyond lat. 75° . Besides being invaluable to navigators, this projection is of the greatest service to the student of physical geography, as it has the advantage of exhibiting at once the whole world, with the true bearings and directions of all the parts perfectly preserved.

Choice of Projections.—The student will readily perceive that all the projections are not equally suitable for all purposes. In choosing projections for the maps of the grand divisions of the earth, and for particular countries, attention must be paid to their form, and to their extent in latitude and longitude, in order that the defects of the projection may as much as possible be thrown into those parts where they will be of the least importance. For the map of Europe the pure conic projection is preferable to all others. It is produced by the development of a cone supposed to intersect the sphere at the lat. of 45° and 65° , these being intermediate between the mean latitude of Europe (55°) and the extremes, 35° and 75° . The central meridian of our maps of Europe generally passes through the twentieth degree of east longitude. The same projection can be applied without any material disadvantage to the maps of Asia and North America, while it is still better adapted to the less extensive regions of the earth's surface, provided they be not situated immediately on the equator. For the maps of Africa and South America, both continents extending on either side of the equator, it is customary to employ certain modifications of the Orthographic Projection.

Geodetical Surveys.—Every student of Trigonometry knows that the three angles of a triangle are equal to 180° (or two right angles), and that if we know any two of them we can instantly calculate the third. Moreover, when we know each of the angles of a triangle (i.e., their measure in degrees) we also know the *proportionate lengths* of the opposite sides, though not, of course, their absolute lengths. But if the length of one side is known, or if we can actually measure it, we can easily determine by means of the theodolite the exact length of the remaining sides. Hence, when two angles of a triangle are known, as also the length of one side, we can at once find out all we want to know about the triangle. On these simple truths depend, not only the exact measurement of the shape and size of a field, but also the Geodetical or Trigonometrical surveys of kingdoms and continents. The measured line from which the rest are calculated is called the *base-line*. However large the triangle may be, and however difficult to measure it in detail by the foot-rule or standard

yard, when once the base-line and angles are determined, the merest tyro in trigonometry can readily tell the exact dimensions and area of the triangle. In extensive geodetical surveys a level plain of sufficient extent is selected for the base-line, and no pains are spared to obtain its length with the utmost precision. In the survey of the United Kingdom the sides of some of the triangles exceeded 100 miles. Two of the principal base-lines measured were—that on Hounslow Heath, about 5 miles long, and that near Lough Foyle, in Ireland, nearly 8 miles in length. By means of this triangulation the whole error in the length of the kingdom is probably less than 3 ft. We have stated that two angles and one side must be known before we can make any progress in our survey. If these three things are not told us, we can generally find them out for ourselves—viz., by measuring the line by the *chain* (66 ft. long, or the $\frac{1}{80}$ part of a mile) so as to ascertain how many feet and inches it contains, and by determining the horizontal angles at either end of the line by means of the *Theodolite*. This is the most common and useful instrument for horizontal-angular measurements (the quadrant being no longer employed), and consists of two graduated circles perpendicular to each other, one of which is fixed in a horizontal and the other in a vertical plane. On the vertical circle is placed a telescope furnished with a spirit-level. The telescope moves vertically about a horizontal axis, which passes through the centre of the vertical arc. By means of this instrument the angles at the extremities of the horizontal base-line (the length of which we have already determined) can be read off with the utmost precision. The merit of applying Trigonometry to geodetic operations belongs to Willebrod Snell, who in 1617 undertook a survey of Holland for the double purpose of establishing the geographical position of the principal cities in that country, and measuring a degree of the terrestrial meridian (see p. 19). Since that time, such has been the progress of geodetic triangulation that now every country in Europe has been carefully surveyed, together with India, the United States, and various other countries.

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